North of the Delta
Offstream Storage Investigation

# Progress Report

## Appendix M: Sites Offstream Storage Project, Power Cost Study

**May 2000**

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Offstream Storage Investigation

# Progress Report

## Appendix M: Sites Offstream Storage Project, Power Cost Study

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# Contents



# Tables



# Figures

# Sites Offstream Storage Project
# Power Cost Study

## Objectives

The main objective of the study is to determine the energy costs and revenues associated with the pumping of the scheduled inflows and with power generated by the release of the scheduled outflows at the proposed pumped-storage hydroelectric powerplant between the existing Funks Reservoir and the proposed 1.8 maf Sites Reservoir. The study does not include costs associated with any additional pumping/generating plants required to transport water from the river to Funks Reservoir. The study also does not include the cost of energy consumed during the initial filling of the reservoir. Two alternative operations are considered: (1) an operation with existing storage capability at Funks Reservoir to accommodate water needs only, which will be referred to as minimal operation; and (2) an operation with an enlarged Funks Reservoir to maximize power operations which will be referred to as optimized operation.

The following are the other objectives of the study:

1) Verify if pumpback is economical and requires the expansion of Funks Reservoir.
2) Determine availability and cost of transmission interconnection.
3) Establish additional factors that can affect the feasibility of the proposed pumped-storage project.
4) Summarize information on pumped-storage technology, including projects constructed this decade and current license applications for pumped-storage hydroelectric powerplants.
5) Establish if pumped-storage is competitive in the present state of deregulation of the electric power utility system.

## Methods

The study is based on the Division of Planning and Local Assistance's Sites Reservoir Study 656, which consists of 74 years of simulated operation. These data, shown in Tables 4-7 in the Attachment, are based on hydrology for 1921 through 1994 and include monthly inflow from Sacramento River diversion, outflow, reservoir storage, and end-of-month head (difference in elevation between Funks and Sites). The average monthly head shown on Table 8 of the Attachment was calculated and used in the study.

Figure 1 shows the range of the calculated average monthly heads over the study period while Figure 2 shows the variation of the average monthly head used in the study. Based on the available head, the study establishes the amount of power to pump the inflows (in MW) and the power generated when the outflows are released through the generators.

For the minimal operation, the average monthly pumping rates were calculated in cubic feet per second based on the monthly inflow and were used to compute the monthly pumping energies and associated costs. Likewise, the average monthly released flows were calculated based on the monthly outflow and used for computing the monthly generated energies and associated revenues. The plant operates twenty-four hours a day at the average pumping or generating discharge rates computed above, without maximizing off-peak pumping or on-peak generation.

For the optimized operation, the plant is assumed to operate at the rated capacities of 6,800 cfs in the pumping mode and 9,064 cfs in the generating mode. To be able to operate at the rated pumping and generating capacities, Funks Reservoir must be enlarged to accommodate the maximum additional daily storage capacity with the pumps operating at rated capacity (6,800 cfs) during the duration of the off-peak hours (ten hours daily). On pumpback, whatever capacity was pumped into Sites must be the same capacity to be discharged to Funks so as not to affect the scheduled inflows and outflows. Additional assumptions used in the study are shown in the Attachment. The amounts of energy consumed for pumping and produced by generation are then determined for two modes of operation:

1) Seasonal operation – Water is generally pumped into the reservoir in the winter and released from the reservoir in the summer in the amounts indicated by the inflow and outflow data provided by the Division of Planning and Local Assistance. Water is pumped during the off-peak hours at the rated capacities of 6,800 cfs to minimize pumping energy costs unless additional on-peak pumping is required to move the total inflow. Water is released during the on-peak hours to maximize revenue generated unless additional off-peak generation is required to move the total outflow.
2) Daily pumpback operation – After the plant has pumped or released the required amount for seasonal operation, the remaining hours are made available for pumpback operation. During pumpback operation, pumping is scheduled during the off-peak hours to minimize pumping energy costs and generation is scheduled during the on-peak hours to maximize the generated revenues. Since the primary purpose of the plant is to store water during periods of excess inflows and release water during the dry seasons, the daily pumpback operation is optional and used only when economically justified.

The cost of energy consumed for pumping and revenue produced during generation is determined by the projected energy price for 1999 as shown in Table 3 under the Discussion section.

## Result

The annual pumping cost and generation income for the minimal operation is shown on Figure 3. Of the 72 years examined, 40 years (55 percent) of the study period resulted in the annual pumping costs exceeding the generation income. Figure 4 shows the average monthly pumping cost and generation income, and Table 1 summarizes the range of annual operation in terms of MWh and dollars, which excludes the first and last years of the study due to incomplete yearly data. The average annual energy cost and revenue are 24.9 and 25.7 $/MWh, respectively.

### Table 1. Minimal Operation

| 72-Year Range | Annual Operation | | | |
|---|---|---|---|---|
| | Energy Consumption (MWh) | Energy Production (MWh) | Energy Cost ($) | Energy Revenue ($) |
| Max | 350,462 | 260,743 | 8,990,537 | 6,330,848 |
| Min | 0 | 0 | 0 | 0 |
| Avg | 106,705 | 74,961 | 2,657,206 | 1,925,370 |

For the optimized operation with an enlarged Funks Reservoir and no pumpback operation, Figure 5 shows 39 years (53 percent) of the study period resulted in the annual seasonal generation income exceeding the pumping cost. The plant can also generate additional revenue as shown in Figure 6 if pumpback is used. The pumpback analysis shows economical operation for all months of every year; however the benefits are only significant during the summer months when the on-peak and off-peak differentials are large. Incorporating pumpback with the seasonal operation results in 57 years (77 percent) of the time that annual generation exceeded the pumping costs and also results in a more substantial generation revenue over the pumping costs shown in Figure 7. The range of annual operation in terms of MWh and dollars is summarized in Table 2 below for both the seasonal and pumpback modes. Figures 8 and 9 also show the average monthly pumping cost and generation income for the seasonal and pumpback modes. The average combined seasonal and pumpback energy cost and revenue are 17.9 and 29.6 $/MWh, respectively.

### Table 2. Optimized Operation

| Mode of Operation | 72-Year Range | Annual Operation | | | |
|---|---|---|---|---|---|
| | | Energy Consumption (MWh) | Energy Production (MWh) | Energy Cost ($) | Energy Revenue ($) |
| Seasonal Without Pumpback | Max | 350,462 | 260,743 | 8,437,045 | 7,889,120 |
| | Min | 0 | 0 | 0 | 0 |
| | Avg | 106,705 | 74,961 | 2,399,642 | 2,459,610 |
| Pumpback and No Seasonal | Max | 691,325 | 529,807 | 11,987,731 | 15,403,745 |
| | Min | 217,675 | 166,819 | 3,645,719 | 4,861,268 |
| | Avg | 447,204 | 342,721 | 7,492,857 | 9,913,321 |
| Combined Seasonal and Pumpback | Max | 799,973 | 625,161 | 15,032,086 | 18,362,605 |
| | Min | 223,201 | 166,819 | 3,770,901 | 4,861,268 |
| | Avg | 553,909 | 417,682 | 9,892,498 | 12,372,931 |

The optimized operation maximizes off-peak pumping to operate economically; this often results in operating the plant at maximum capacity for all off-peak hours of the day, especially if pumpback is incorporated. To accommodate such operation, Funks Reservoir needs to be enlarged to have an operating storage of 5.6 taf in addition to any dead-pool storage required.

## Additional Cost And Revenue

PG&E performed an Informational Review to determine the transmission interconnection costs of the proposed pumped-storage hydroelectric powerplant at Sites Reservoir. A report is enclosed that includes a map showing the approximate location of the proposed pumped-storage powerplant and the closest 230 kV line. Based on the previously estimated generation capacity of 162 MW, pumping requirement of 200 MW, and allowance for future expansion, PG&E proposes to loop two 230 kV transmission lines to the pumped-storage facility.

The next step is for PG&E to perform either a Preliminary Facilities Study or a Detailed Facilities Study depending on how much detail DWR requires. The cost of the study will depend on the complexity and the number of alternatives to be studied. The Informational Review Report is included in the Attachment. Note that the location of the proposed pumped-storage facility shown on the map provided by PG&E is incorrect. A letter has been sent to PG&E informing them of the discrepancy, which will be corrected when the decision on when and how to proceed with this project is reached.

Also, the previous estimate of a pumped-storage facility with 162 MW of generating capacity and 200 MW of pump load has now been corrected per Division of Engineering's estimated plant ratings of 192 MW in generating mode and 184 MW in pumping mode. Together with the location of the proposed pumped-storage plant, the change in the unit sizes will be corrected after the decision to proceed is made. The corrected plant ratings will not affect the transmission line capacity because the estimated complex capacity is still 300 MW and the length of the line is about one fifth of the PG&E estimate, which will result in a reduction in the transmission line material and construction costs shown in PG&E's Informational Review.

The California Independent System Operator has currently filed an amendment to its tariff with the Federal Energy Regulatory Commission to include requirements for new generation interconnection. The main premise of new generation interconnection is that new generators will be required to eliminate any impact to the local area as the primary condition for interconnection. If system studies indicate inadequacy of the electrical capabilities of any of the electrical equipment (line circuit breakers, substation transformers, voltage transformers, etc.) in the substation or switchyard at the point of interconnection, then replacing them will become part of the interconnection requirements for the new generator.

Transmission congestion resulting from the interconnection must also be solved by the new generator. More costs will be assessed to the new generator if the interconnection studies performed by the participating transmission owner reveal that local transmission congestion is created and/or electrical equipment capabilities are exceeded within the surrounding area at the point of interconnection. These additional technical problems and costs will only be established after the interconnection studies are done. Once transmission is available, the CAISO also charges usage fees, including grid management and access charges. The grid management charge is based on the pump load and for 1999 is $0.7781/MWh. Methodology for calculating the access charge is under development. Additional costs to consider are those involving the terms and conditions associated with the Federal Energy Regulatory Commission Licensing as a result of the generation feature of the facility.

## Pumped-Storage Technology Information

Current North American Electric Reliability Council generation resources database shows 40 pumped-storage hydroelectric power plants operating in the NERC region. Of the 40, six were constructed within the last ten years. They range in size from the single unit, 5,000 kW Youghiogheny owned by an independent power producer connected to the Pennsylvania Electric Co. system, to the 4-unit, 1,065,000 kW Bad Creek plant owned and operated by Duke Power Co. The latest pumped-storage plant constructed is the 3-unit (847,800 kW) Rocky Mountain Project which is jointly owned and operated by Oglethorpe Power Corp. and other utilities. The remaining three plants are quite small compared to the Bad Creek and Rocky Mountain Projects, having only a combined capacity of 75,500 kW.

From the same database source, two pumped-storage plants are currently under construction: the NA1 (Union Electric Co. owned) has a single 215,000 kW unit scheduled to be in service by May of this year; and Summit Energy (independently-owned but connected to Ohio Edison, Co.) has six 250,000 kW units, three of which are scheduled to be in service by January 2004 with the remaining three by January of 2005. A third plant, the NA1 Richard Russell (owned by the United States Corps of Engineers – Savannah District), has four 85,000 kW units which were supposedly put into service November of 1998. The December 11, 1998, issue of the California Energy Markets Newsletter also noted that Arizona Independent Power applied in October 1998 to the Federal Energy Regulatory Commission for a preliminary permit to build White Tank Mountain, a project with a 1,250,000 kW pumped-storage hydroelectric power plant.

To improve the range of operation, the current technology in hydraulic machinery uses adjustable-speed generators and motor-generators in conjunction with high current capacity, power electronic devices for conventional and pumped-storage hydroelectric power projects.

## Pumped-Storage Role In Deregulation

The deregulation of the electric utility system created a separate market for providing ancillary services to the grid, including the following:

1) regulation
2) voltage support
3) spinning reserves
4) non-spinning reserves
5) replacement reserves
6) black start

Due to the inherent dynamic operating characteristics of hydroelectric generators with motor/generators for pumped-storage, they are excellent participants in the ancillary services market. Their ability to respond to changes in power requirements are steps ahead of the competition and where the ancillary services market puts a premium to this capability. Some of these characteristics include:

1) load following
2) unit commitment
3) reduced system minimum loading
4) voltage and power factor correction (condenser mode)
5) frequency regulation
6) improved system operating reliability
7) black start capability

Therefore, in addition to producing energy, a potentially profitable application of pumped-storage hydroelectric power plants in the deregulated power market is in providing ancillary services such as spinning and non-spinning reserves.

## Discussion

The reason for building a reservoir at the Sites location is to store excess winter flows of the Sacramento River and local streams. Water management is the main purpose of the proposed project; however, this study only focuses on power-related aspects of the project. The study estimates the pumping costs incurred to store the inflows during wet months and income from generation when water outflows are released during the dry months. Even without pumpback, minimal operation costs more than optimized operation because of the assumption to not maximize on-peak generation and to not enlarge Funks Reservoir. An enlarged Funks Reservoir allows maximized off-peak pumping when power costs less.

Pumpback is considered to offset pumping costs; however, with an enlarged Funks Reservoir, net income is generated even without pumpback operation. Pumpback does generate significant additional income, making it logical to incorporate pumpback in between scheduled seasonal operation when the generation revenues are more than the pumping costs. The pumpback operation shown in the study is optimized and requires very efficient scheduling that may be difficult to achieve in actual operations. For the most economic operation, the existing Funks Reservoir must be expanded to accommodate the maximum water that can be stored during the off-peak hours (ten hours per day) at the maximum flow of 6,800 cfs, in addition to any dead-pool storage.

The cost of transmission interconnection will depend on the interconnection studies to be performed by the participating transmission owner, PG&E. PG&E will require a payment to perform the studies and an official request to initiate them. If the interconnection studies indicate that the proposed project will result in local transmission congestion or cause electrical equipment capabilities to be inadequate at the point of interconnection, eliminating the transmission congestion and replacing the affected electrical equipment will certainly add more costs to the project.

Adjustable-speed motor/generator technology is state of the art in pumped-storage hydroelectric powerplant design; it has an advantage over the conventional hydraulic motor/generator because the speed of the unit can be adjusted to allow high turbine efficiency at a wider range of head and flow variations. This technology is suitable for seasonal operation of pumped-storage where the head varies widely as in the case of the Sites Offstream Reservoir Project. If the Sites Offstream Reservoir Project proceeds and the Division of Engineering prepares a specification indicating the ratings (size, operating range, etc.) of the unit, the study will need to be updated to more accurately represent the operation of the plant.

The ancillary services market created by the deregulation of the electric utility industry is an attractive market for hydroelectric power plants due to their inherent operating characteristics, specifically the spinning and supplemental (non-spinning) reserves where their ability to respond quickly to changes and to start and get on line quickly are utilized. Since the project is primarily proposed to store water during the wet months and release the water during the dry months, participation in the ancillary services market will only be employed for as long as the scheduled inflows and outflows are not affected. Even without participation in the ancillary services market, energy revenue is greater than energy cost if pumpback is employed.

The results of the study are based on the projected 1999 energy prices from the December 22, 1998 "1998 Market Clearing Price Forecast for the California Energy Market: Forecast Methodology and Analytical Issues" by the California Energy Commission and are shown on Table 3 below. These prices will fluctuate due to the uncertain conditions resulting from the ongoing developments brought about by deregulation, thus subsequent studies may be more or less favorable depending on the available on-peak and off-peak energy price differentials.

It is often difficult to forecast these differentials. Table 3A below was taken from the CEC report and shows a comparison of the forecasted 1998 energy prices to the actual 1998 energy prices. Only the actual energy prices for the months of April to November of 1998 are available for comparison with the forecasted data, limiting the comparison to that time frame only. There are considerable differences in the forecasted to the actual energy prices, especially during the months of May through August where they ranged from a low of 16 percent to a high of 71 percent. Among the reasons for these variation in prices are fuel prices, CEC staffs' modeling of the California Power Exchange market, hydro availability, CEC staffs' modeling reliance on historical utility load shapes, transmission congestion, summer peak temperatures, and the future pace and extent of deregulation for states outside of California. The prices shown are average prices only; hourly prices fluctuate much more and range from practically nothing to hundreds of dollars per MWh.

### Table 3. 1999 Projected Energy Prices

| Month | On-peak $/MWh | Off-peak $/MWh |
|---|---|---|
| Jan | 30.60 | 22.36 |
| Feb | 27.55 | 20.13 |
| Mar | 26.29 | 19.21 |
| Apr | 24.43 | 16.10 |
| May | 26.44 | 8.92 |
| Jun | 25.56 | 6.43 |
| Jul | 30.77 | 14.83 |
| Aug | 41.10 | 19.71 |
| Sep | 35.01 | 21.11 |
| Oct | 25.53 | 18.08 |
| Nov | 26.40 | 19.29 |
| Dec | 29.72 | 21.72 |
| Avg | 29.12 | 17.32 |

### Table 3A. Comparison of Forecasted to Actual CalPX Energy Prices

| Mo./Year | Projected On-Peak ($/MWh) | Actual On-Peak ($/MWh) | % Diff. | Projected Off-Peak ($/MWh) | Actual Off-Peak ($/MWh) | % Diff. |
|---|---|---|---|---|---|---|
| Apr-98 | 24.1 | 25.9 | 7 | 15.9 | 17.0 | 6 |
| May-98 | 26.6 | 15.6 | -71 | 9.0 | 5.8 | -55 |
| Jun-98 | 26.6 | 16.7 | -59 | 6.7 | 4.0 | -68 |
| Jul-98 | 33.9 | 40.3 | 16 | 16.3 | 19.7 | 17 |
| Aug-98 | 37.4 | 49.6 | 25 | 17.9 | 23.8 | 25 |
| Sep-98 | 35.9 | 39.6 | 9 | 21.6 | 23.8 | 9 |
| Oct-98 | 27.8 | 29.8 | 7 | 19.7 | 21.5 | 8 |
| Nov-98 | 28.9 | 28.5 | -1 | 21.1 | 21.3 | 1 |

The study only addresses power-related costs and does not include costs for construction, O&M, environmental studies, etc. A complete economic analysis would require cost projections from other DWR divisions. A time frame of when the plant would be constructed and operated would also be necessary to project and present the costs and revenues. In addition, as the electric power industry gains experience with deregulation, projections for the price for energy, ancillary services, and transmission will be more accurate and should be updated as more information on this project becomes available**.** Currently few projections even exist for beyond ten years.

final draft

**Figure 1 - SITES RESERVOIR STUDY 656**
**RANGE OF AVERAGE MONTHLY HEAD**
**(difference between Funks & Sites)**

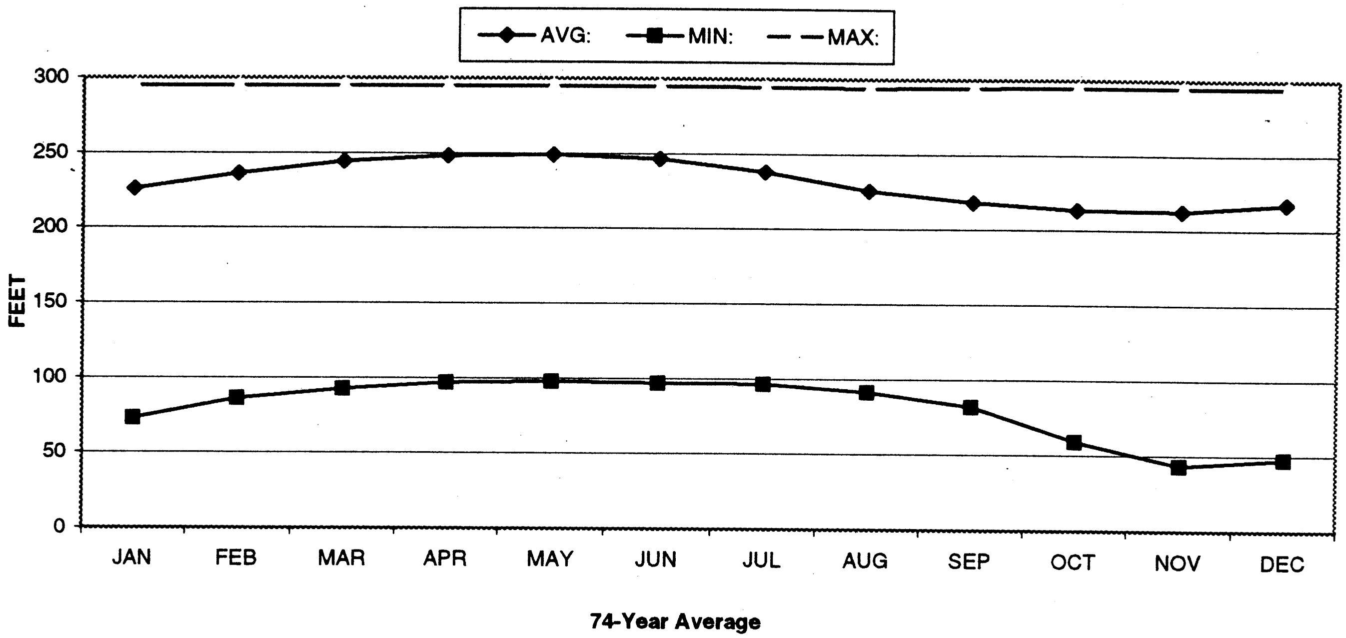
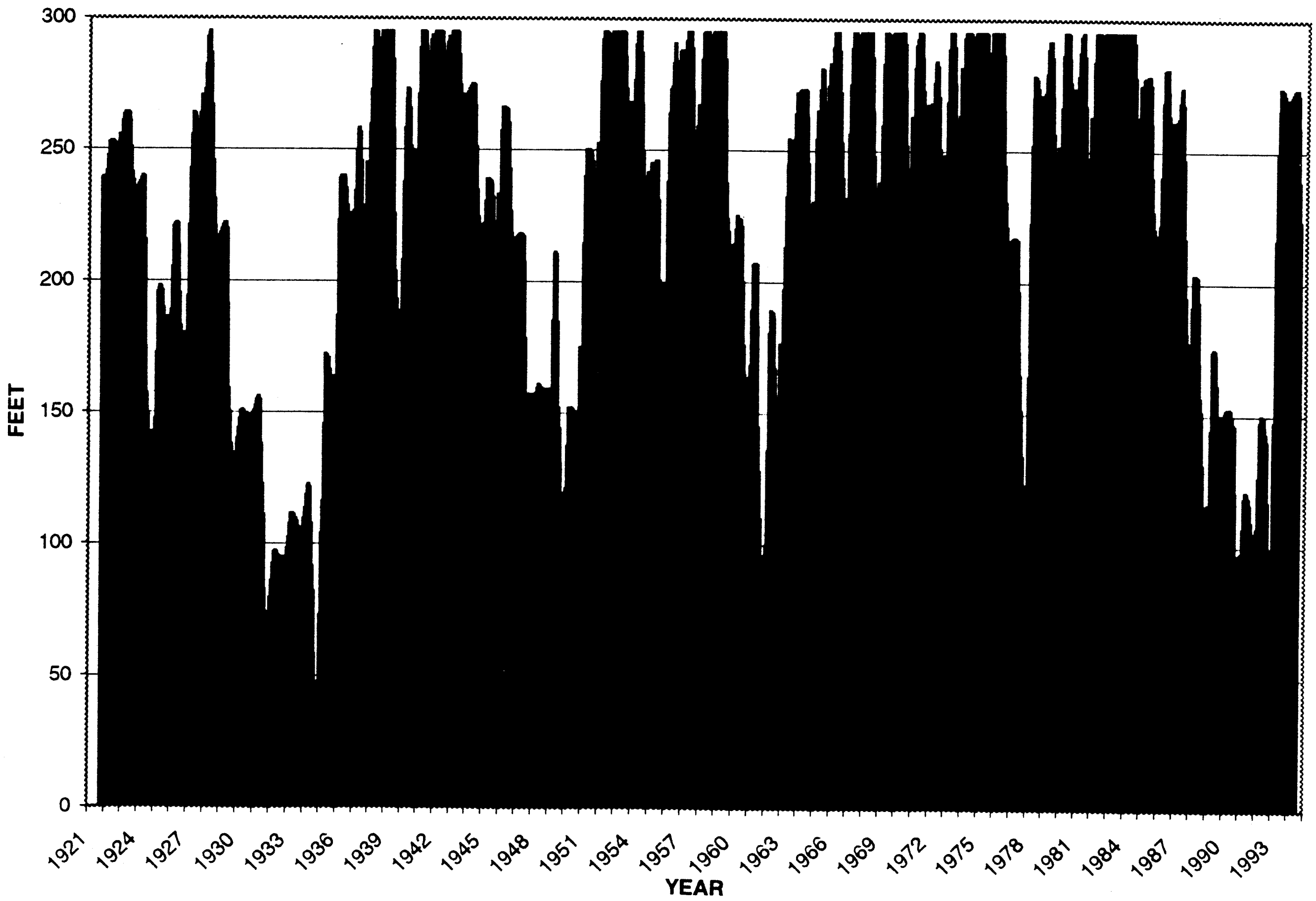



**Figure 2 - SITES RESERVOIR STUDY 656**
**AVERAGE MONTHLY HEAD**
**(difference between Funks & Sites)**



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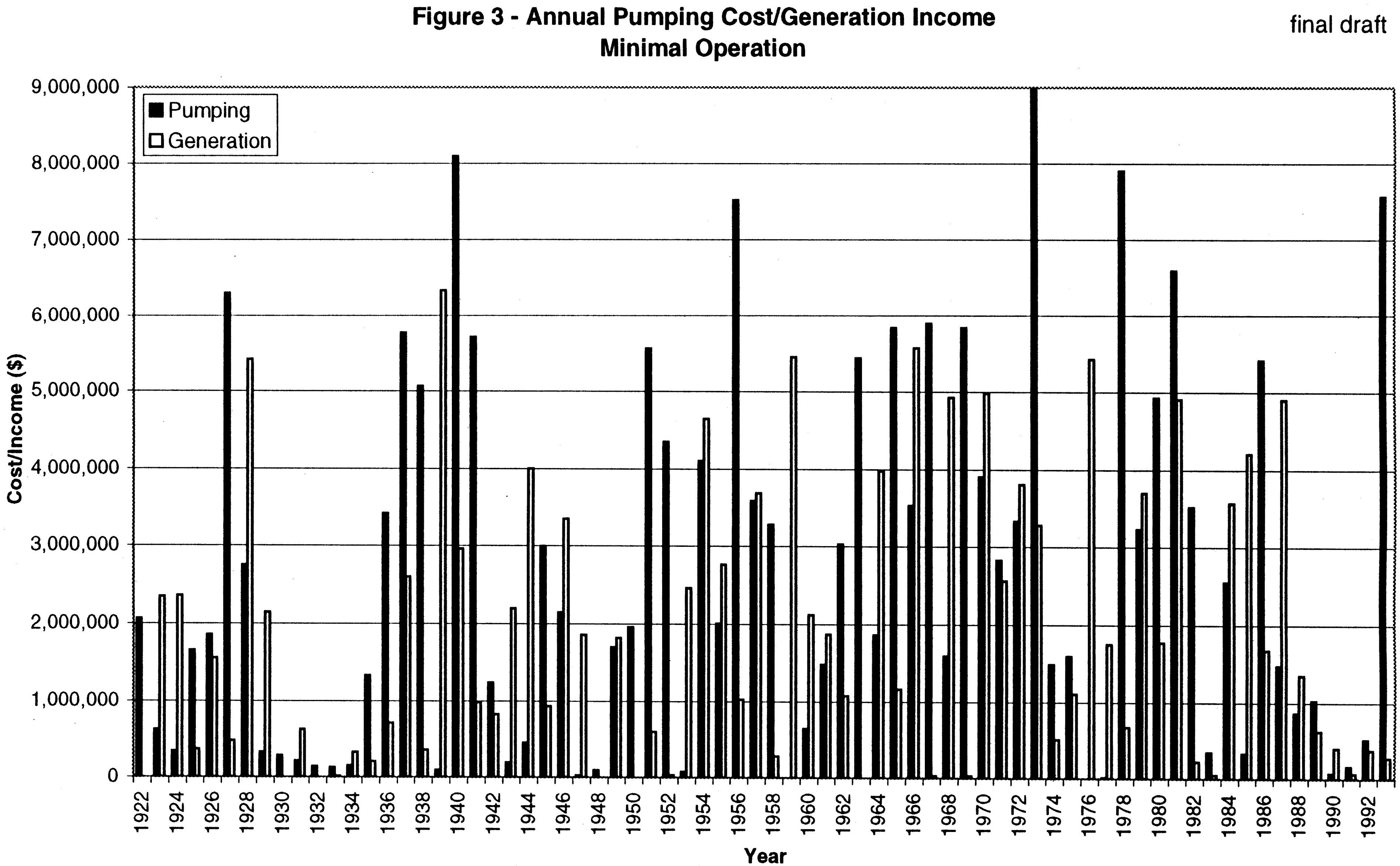

Figure 3 - Annual Pumping Cost/Generation Income
Minimal Operation
Pumping
Generation
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Cost/Income ($)
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Year

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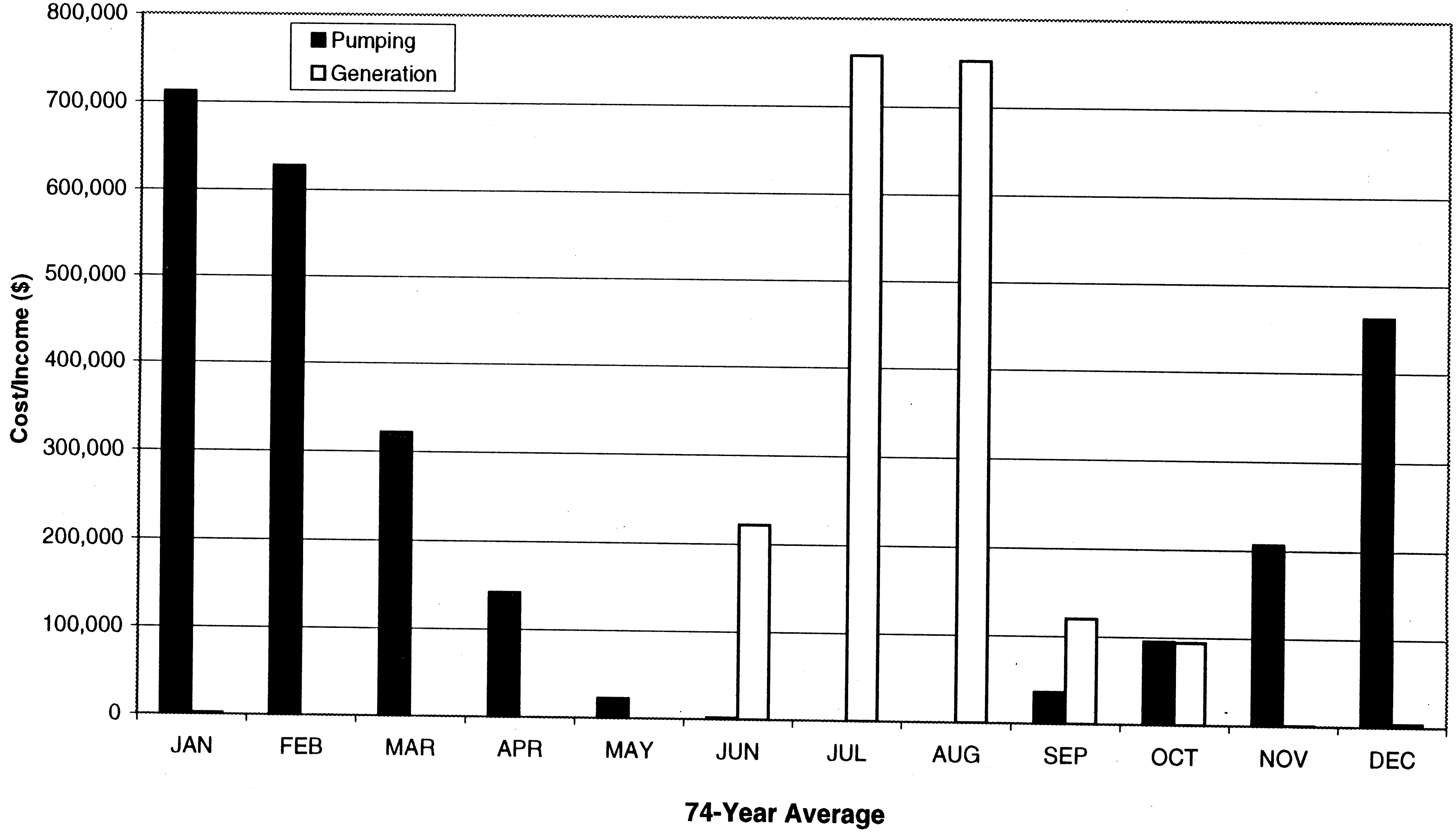
## Figure 4 - Average Monthly Pumping Cost/Generation Income
## Minimal Operation



# Figure 6 - ANNUAL PUMPING COST/GENERATION INCOME
## Optimized Operation (Pumpback)

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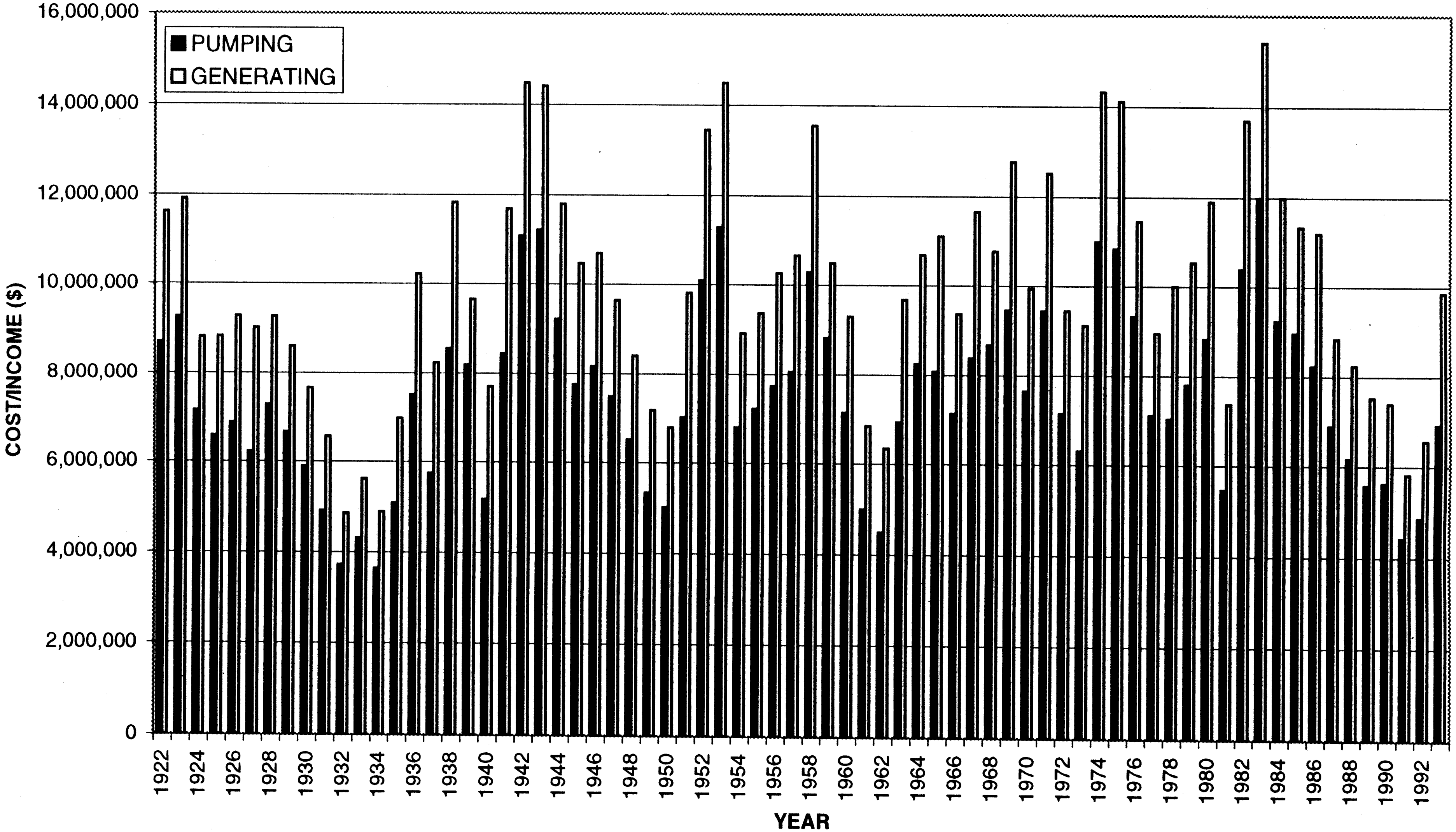
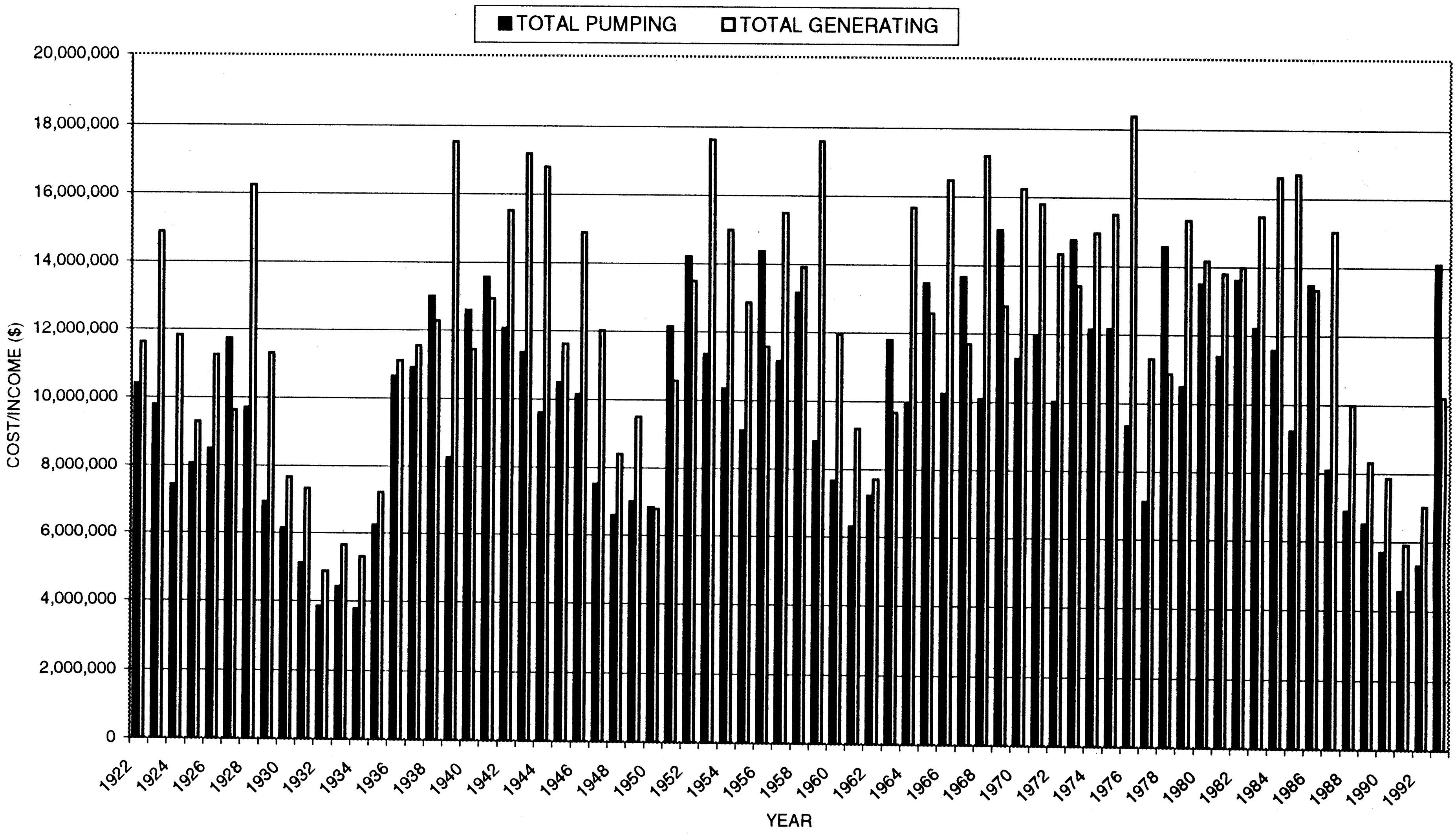


final draft

## Figure 7 - ANNUAL PUMPING COST/GENERATION INCOME
## Optimized Operation (Seasonal & Pumpback)



final draft

**Figure 8 - Average Monthly Pumping Cost & Generation Income
Optimized Operation (Seasonal)**

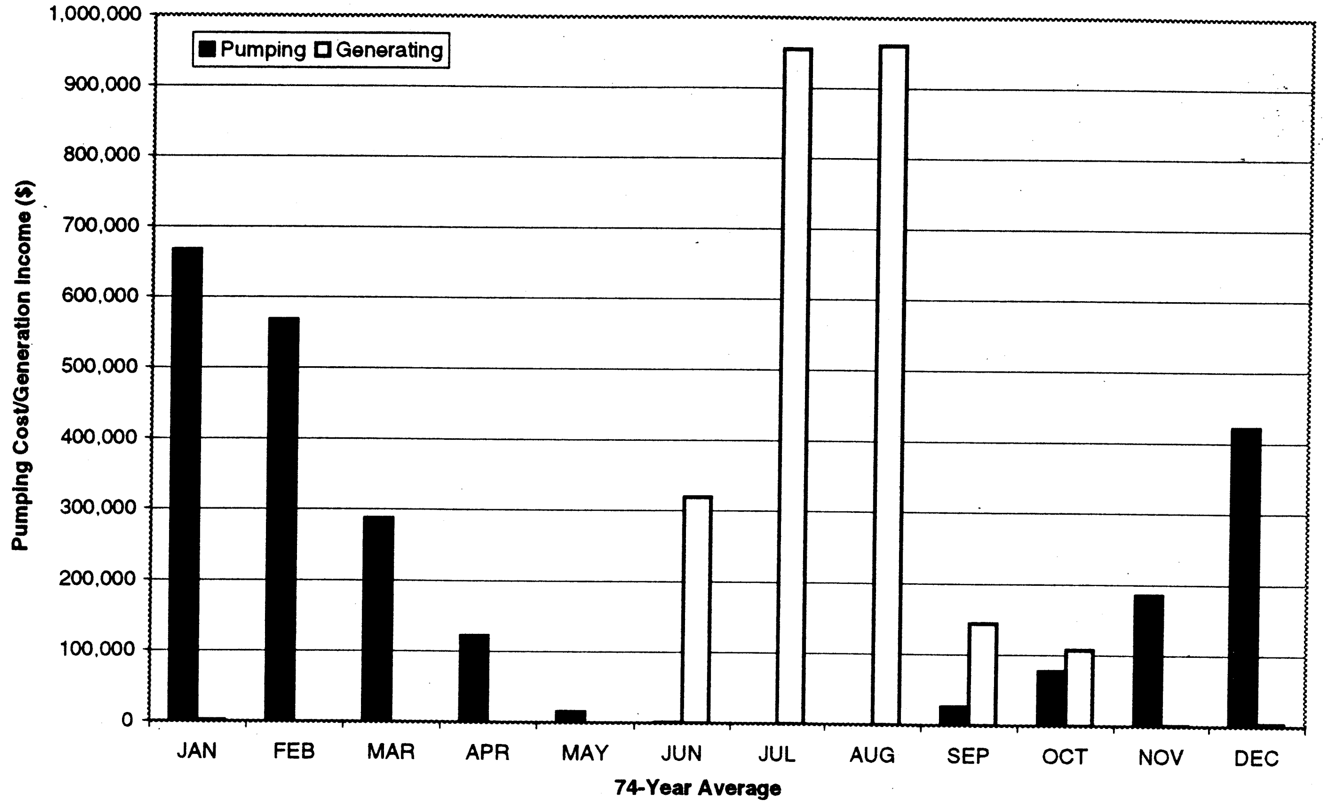
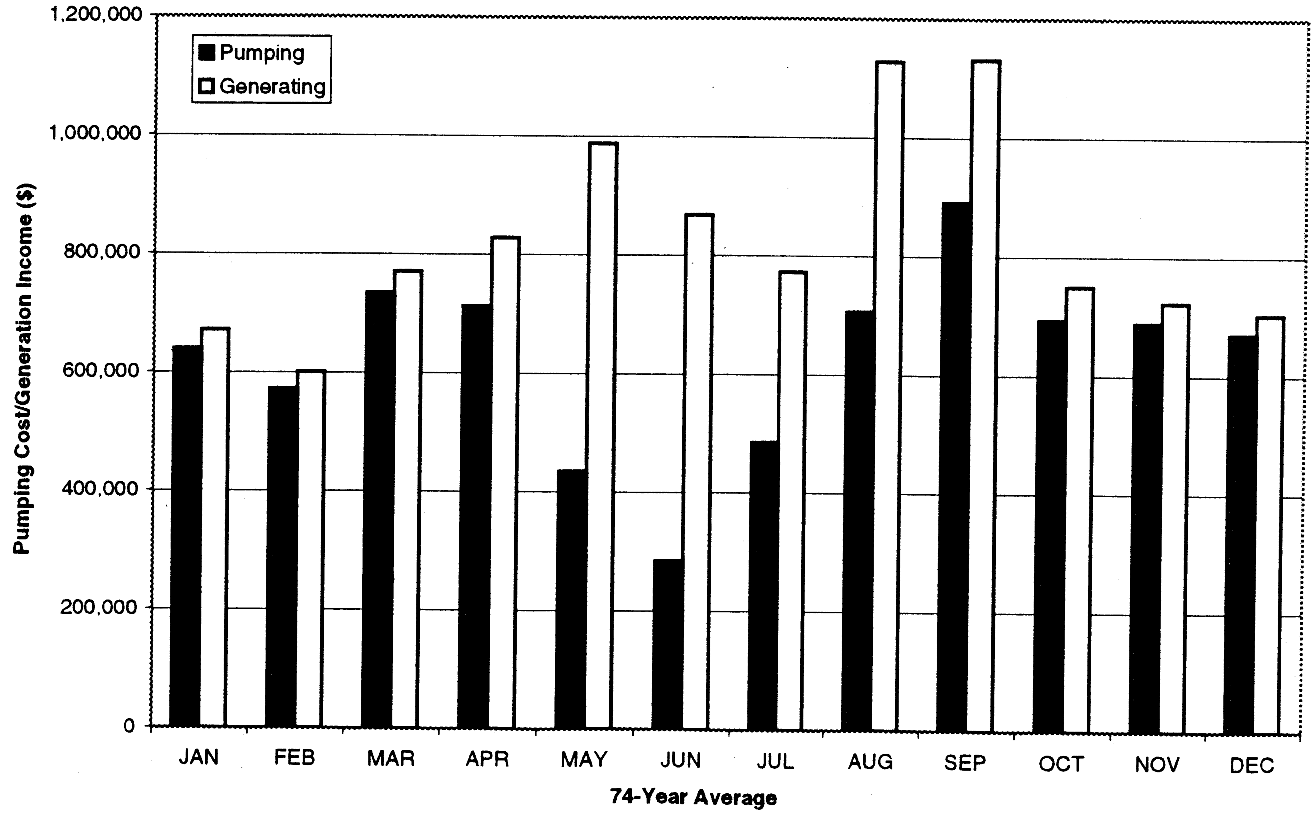



**Figure 9 - Average Monthly Pumping Cost & Generation Income
Optimized Operation (Pumpback)**



# Attachments

## Table 4 - Study 656: Sites Reservoir monthly inflow in TAF

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 0 | 2 | 15 | 17 |
| 1922 | 37 | 123 | 15 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 93 | 280 |
| 1923 | 44 | 24 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 79 |
| 1924 | 13 | 7 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 56 |
| 1925 | 37 | 254 | 15 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 9 | 336 |
| 1926 | 16 | 224 | 16 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 45 | 322 |
| 1927 | 128 | 280 | 115 | 244 | 0 | 0 | 0 | 0 | 0 | 0 | 186 | 15 | 968 |
| 1928 | 37 | 233 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 340 |
| 1929 | 13 | 7 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 9 | 61 |
| 1930 | 16 | 13 | 31 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 69 |
| 1931 | 13 | 7 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 9 | 61 |
| 1932 | 16 | 13 | 16 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 54 |
| 1933 | 13 | 7 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 42 |
| 1934 | 13 | 7 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 56 |
| 1935 | 104 | 43 | 15 | 234 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 413 |
| 1936 | 271 | 254 | 15 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 556 |
| 1937 | 6 | 125 | 239 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 189 | 278 | 840 |
| 1938 | 88 | 280 | 189 | 2 | 4 | 0 | 0 | 0 | 0 | 84 | 0 | 0 | 647 |
| 1939 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 17 |
| 1940 | 271 | 254 | 249 | 92 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 278 | 1159 |
| 1941 | 322 | 188 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 122 | 15 | 36 | 689 |
| 1942 | 0 | 0 | 0 | 3 | 4 | 0 | 0 | 0 | 0 | 88 | 15 | 45 | 155 |
| 1943 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 9 | 25 |
| 1944 | 16 | 13 | 16 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 59 |
| 1945 | 0 | 135 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 291 | 429 |
| 1946 | 254 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 8 | 266 |
| 1947 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 1948 | 0 | 0 | 4 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |
| 1949 | 0 | 0 | 332 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 337 |
| 1950 | 7 | 104 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 276 | 396 |
| 1951 | 262 | 224 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 283 | 776 |
| 1952 | 384 | 80 | 0 | 2 | 4 | 0 | 0 | 0 | 13 | 20 | 0 | 0 | 503 |
| 1953 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| 1954 | 234 | 146 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 86 | 498 |
| 1955 | 7 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 305 | 326 |
| 1956 | 368 | 259 | 6 | 25 | 234 | 0 | 0 | 0 | 0 | 140 | 4 | 3 | 1039 |
| 1957 | 4 | 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 129 | 0 | 234 | 459 |
| 1958 | 270 | 14 | 0 | 2 | 4 | 8 | 0 | 0 | 61 | 3 | 0 | 0 | 362 |
| 1959 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1960 | 7 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 12 | 106 |
| 1961 | 40 | 214 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 283 |
| 1962 | 0 | 278 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 238 | 658 |
| 1963 | 1 | 259 | 56 | 248 | 0 | 0 | 0 | 0 | 0 | 44 | 238 | 0 | 846 |
| 1964 | 5 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 241 | 263 |
| 1965 | 292 | 0 | 0 | 243 | 0 | 0 | 0 | 0 | 0 | 0 | 244 | 3 | 782 |
| 1966 | 166 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 265 | 450 |
| 1967 | 292 | 235 | 176 | 2 | 4 | 8 | 0 | 0 | 0 | 26 | 0 | 0 | 743 |
| 1968 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 216 | 218 |
| 1969 | 327 | 345 | 0 | 2 | 4 | 0 | 0 | 0 | 30 | 3 | 0 | 0 | 711 |
| 1970 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 239 | 286 | 525 |
| 1971 | 250 | 0 | 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 325 |
| 1972 | 0 | 0 | 239 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 170 | 444 |
| 1973 | 391 | 187 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 255 | 264 | 1097 |
| 1974 | 51 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 63 | 49 | 0 | 0 | 165 |
| 1975 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 196 | 0 | 0 | 208 |
| 1976 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1977 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| 1978 | 413 | 318 | 309 | 236 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 1283 |
| 1979 | 30 | 181 | 81 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 89 | 410 |
| 1980 | 337 | 244 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 591 |
| 1981 | 123 | 132 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 266 | 290 | 851 |
| 1982 | 315 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 64 | 3 | 0 | 0 | 384 |
| 1983 | 0 | 0 | 0 | 2 | 4 | 8 | 0 | 0 | 23 | 3 | 0 | 0 | 40 |
| 1984 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 283 | 61 | 344 |
| 1985 | 5 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 48 |
| 1986 | 34 | 378 | 337 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 765 |
| 1987 | 3 | 22 | 164 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 205 |
| 1988 | 142 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 142 |
| 1989 | 0 | 0 | 245 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 259 |
| 1990 | 9 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| 1991 | 0 | 0 | 44 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 |
| 1992 | 4 | 99 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 141 |
| 1993 | 400 | 369 | 268 | 225 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 1278 |
| 1994 | 7 | 30 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | ---- | ---- | ---- | 43 |
| AVG: | 95 | 93 | 49 | 24 | 4 | 0 | 0 | 0 | 4 | 13 | 30 | 64 | 380 |
| MIN: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX: | 413 | 378 | 337 | 248 | 234 | 8 | 0 | 0 | 64 | 196 | 283 | 305 | 1283 |

## Table 5 - Study 656: Sites Reservoir monthly outflow in TAF

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 0 | 0 | 0 | 0 |
| 1922 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1923 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 263 | 0 | 56 | 0 | 0 | 352 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 375 | 189 | 19 | 60 | 18 | 0 | 0 | 661 |
| 1925 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 59 | 0 | 7 | 0 | 0 | 70 |
| 1926 | 0 | 0 | 0 | 0 | 0 | 0 | 114 | 152 | 0 | 50 | 0 | 0 | 316 |
| 1927 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 0 | 0 | 64 |
| 1928 | 0 | 0 | 0 | 0 | 0 | 231 | 329 | 237 | 81 | 72 | 0 | 0 | 950 |
| 1929 | 0 | 0 | 0 | 0 | 0 | 35 | 330 | 90 | 8 | 79 | 0 | 0 | 542 |
| 1930 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1931 | 0 | 0 | 0 | 0 | 0 | 10 | 109 | 0 | 49 | 79 | 0 | 0 | 247 |
| 1932 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1933 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 6 |
| 1934 | 0 | 0 | 0 | 0 | 0 | 0 | 62 | 10 | 31 | 75 | 0 | 0 | 178 |
| 1935 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 48 |
| 1936 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | 40 | 10 | 0 | 0 | 113 |
| 1937 | 0 | 0 | 0 | 0 | 0 | 31 | 237 | 121 | 75 | 0 | 0 | 0 | 464 |
| 1938 | 0 | 0 | 0 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 1 | 4 | 56 |
| 1939 | 2 | 0 | 0 | 0 | 0 | 305 | 418 | 308 | 69 | 68 | 0 | 0 | 1170 |
| 1940 | 0 | 0 | 0 | 0 | 0 | 0 | 180 | 217 | 32 | 33 | 0 | 0 | 462 |
| 1941 | 0 | 0 | 0 | 0 | 0 | 0 | 107 | 38 | 0 | 0 | 0 | 0 | 145 |
| 1942 | 2 | 0 | 0 | 0 | 0 | 0 | 103 | 20 | 0 | 0 | 0 | 0 | 125 |
| 1943 | 0 | 0 | 0 | 0 | 0 | 0 | 220 | 92 | 16 | 0 | 0 | 0 | 328 |
| 1944 | 0 | 0 | 0 | 0 | 0 | 0 | 189 | 267 | 116 | 59 | 0 | 0 | 631 |
| 1945 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 68 | 0 | 0 | 0 | 148 |
| 1946 | 0 | 0 | 0 | 0 | 0 | 0 | 137 | 283 | 54 | 65 | 0 | 0 | 539 |
| 1947 | 0 | 0 | 0 | 0 | 0 | 0 | 144 | 236 | 0 | 0 | 0 | 0 | 380 |
| 1948 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1949 | 0 | 0 | 0 | 0 | 0 | 14 | 306 | 89 | 0 | 63 | 0 | 0 | 472 |
| 1950 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1951 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 84 |
| 1952 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 |
| 1953 | 2 | 0 | 0 | 0 | 0 | 0 | 216 | 142 | 0 | 0 | 0 | 0 | 360 |
| 1954 | 0 | 0 | 0 | 0 | 0 | 222 | 313 | 203 | 39 | 29 | 0 | 0 | 806 |
| 1955 | 0 | 0 | 0 | 0 | 0 | 0 | 274 | 217 | 0 | 40 | 0 | 0 | 531 |
| 1956 | 0 | 0 | 0 | 0 | 0 | 0 | 138 | 22 | 0 | 0 | 0 | 0 | 160 |
| 1957 | 0 | 0 | 0 | 0 | 0 | 175 | 254 | 189 | 0 | 0 | 0 | 0 | 618 |
| 1958 | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 0 | 1 | 4 | 44 |
| 1959 | 2 | 0 | 0 | 0 | 0 | 279 | 324 | 291 | 0 | 82 | 0 | 0 | 978 |
| 1960 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 268 | 52 | 57 | 0 | 0 | 408 |
| 1961 | 0 | 0 | 0 | 0 | 0 | 0 | 267 | 150 | 0 | 83 | 0 | 0 | 500 |
| 1962 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 219 | 0 | 0 | 0 | 0 | 224 |
| 1963 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1964 | 0 | 0 | 0 | 0 | 0 | 0 | 240 | 255 | 91 | 62 | 0 | 0 | 648 |
| 1965 | 0 | 0 | 0 | 0 | 0 | 0 | 148 | 37 | 0 | 0 | 0 | 0 | 185 |
| 1966 | 0 | 0 | 0 | 0 | 0 | 179 | 260 | 277 | 74 | 166 | 0 | 0 | 956 |
| 1967 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 |
| 1968 | 2 | 0 | 0 | 0 | 0 | 260 | 281 | 215 | 75 | 30 | 0 | 0 | 863 |
| 1969 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 |
| 1970 | 2 | 0 | 0 | 0 | 0 | 114 | 344 | 265 | 53 | 34 | 0 | 0 | 812 |
| 1971 | 0 | 0 | 0 | 0 | 0 | 0 | 212 | 160 | 0 | 0 | 0 | 0 | 372 |
| 1972 | 0 | 0 | 0 | 0 | 0 | 52 | 262 | 284 | 0 | 0 | 0 | 0 | 598 |
| 1973 | 0 | 0 | 0 | 0 | 0 | 145 | 230 | 166 | 0 | 0 | 0 | 0 | 541 |
| 1974 | 0 | 0 | 0 | 0 | 0 | 0 | 76 | 0 | 0 | 0 | 1 | 4 | 81 |
| 1975 | 2 | 0 | 0 | 0 | 0 | 0 | 170 | 0 | 0 | 0 | 1 | 4 | 177 |
| 1976 | 2 | 0 | 0 | 0 | 0 | 226 | 347 | 230 | 71 | 80 | 0 | 0 | 956 |
| 1977 | 0 | 0 | 0 | 0 | 0 | 264 | 25 | 86 | 64 | 68 | 0 | 0 | 507 |
| 1978 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 68 | 0 | 0 | 0 | 0 | 91 |
| 1979 | 0 | 0 | 0 | 0 | 0 | 153 | 252 | 174 | 39 | 0 | 0 | 0 | 618 |
| 1980 | 0 | 0 | 0 | 0 | 0 | 0 | 225 | 49 | 0 | 0 | 0 | 0 | 274 |
| 1981 | 0 | 0 | 0 | 0 | 0 | 241 | 285 | 252 | 57 | 9 | 0 | 0 | 844 |
| 1982 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 1 | 4 | 35 |
| 1983 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 7 |
| 1984 | 2 | 0 | 0 | 0 | 0 | 107 | 249 | 208 | 0 | 0 | 0 | 0 | 566 |
| 1985 | 0 | 0 | 0 | 0 | 0 | 84 | 295 | 241 | 32 | 73 | 0 | 0 | 725 |
| 1986 | 0 | 0 | 0 | 0 | 0 | 0 | 203 | 63 | 0 | 0 | 0 | 0 | 266 |
| 1987 | 0 | 0 | 0 | 0 | 0 | 180 | 355 | 262 | 74 | 66 | 0 | 0 | 937 |
| 1988 | 0 | 0 | 0 | 0 | 0 | 111 | 148 | 8 | 47 | 94 | 0 | 0 | 408 |
| 1989 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 134 | 0 | 0 | 0 | 0 | 134 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 0 | 0 | 129 | 0 | 0 | 156 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 21 | 0 | 0 | 28 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 17 | 93 | 0 | 0 | 140 |
| 1993 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 35 |
| 1994 | 0 | 0 | 0 | 0 | 0 | 48 | 290 | 224 | 72 | ---- | ---- | ---- | 634 |
| AVG: | 0 | 0 | 0 | 0 | 0 | 53 | 139 | 112 | 22 | 27 | 0 | 0 | 349 |
| MIN: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX: | 2 | 0 | 0 | 0 | 0 | 375 | 418 | 308 | 116 | 166 | 1 | 4 | 1170 |

**Table 6 - Study 656: Sites Reservoir end of month storage in TAF**

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 998 | 1,000 | 1,018 |
| 1922 | 1,057 | 1,180 | 1,195 | 1,201 | 1,198 | 1,192 | 1,185 | 1,179 | 1,174 | 1,172 | 1,177 | 1,273 |
| 1923 | 1,319 | 1,343 | 1,348 | 1,349 | 1,345 | 1,339 | 1,299 | 1,029 | 1,025 | 967 | 968 | 973 |
| 1924 | 987 | 995 | 1,010 | 1,011 | 1,008 | 627 | 434 | 412 | 350 | 330 | 332 | 349 |
| 1925 | 387 | 641 | 656 | 663 | 661 | 657 | 648 | 585 | 582 | 573 | 587 | 598 |
| 1926 | 615 | 839 | 855 | 860 | 857 | 852 | 733 | 576 | 573 | 521 | 537 | 584 |
| 1927 | 713 | 993 | 1,108 | 1,351 | 1,347 | 1,341 | 1,334 | 1,264 | 1,259 | 1,256 | 1,442 | 1,461 |
| 1928 | 1,500 | 1,733 | 1,800 | 1,798 | 1,794 | 1,555 | 1,219 | 976 | 891 | 817 | 818 | 823 |
| 1929 | 836 | 844 | 859 | 861 | 858 | 818 | 483 | 389 | 380 | 300 | 313 | 323 |
| 1930 | 340 | 354 | 385 | 390 | 388 | 385 | 382 | 379 | 377 | 376 | 377 | 381 |
| 1931 | 394 | 401 | 416 | 418 | 417 | 404 | 291 | 289 | 238 | 158 | 171 | 181 |
| 1932 | 197 | 211 | 226 | 232 | 231 | 229 | 227 | 225 | 224 | 223 | 223 | 227 |
| 1933 | 240 | 247 | 263 | 265 | 264 | 262 | 259 | 257 | 256 | 249 | 249 | 253 |
| 1934 | 266 | 273 | 288 | 291 | 289 | 287 | 222 | 210 | 178 | 102 | 104 | 120 |
| 1935 | 224 | 267 | 282 | 516 | 514 | 511 | 507 | 503 | 453 | 451 | 454 | 470 |
| 1936 | 742 | 997 | 1,011 | 1,018 | 1,015 | 1,010 | 1,003 | 935 | 891 | 879 | 884 | 890 |
| 1937 | 898 | 1,024 | 1,262 | 1,263 | 1,260 | 1,223 | 978 | 851 | 773 | 771 | 960 | 1,241 |
| 1938 | 1,331 | 1,612 | 1,800 | 1,800 | 1,800 | 1,792 | 1,732 | 1,725 | 1,719 | 1,800 | 1,800 | 1,800 |
| 1939 | 1,800 | 1,800 | 1,800 | 1,797 | 1,793 | 1,481 | 1,055 | 741 | 669 | 599 | 601 | 618 |
| 1940 | 890 | 1,145 | 1,393 | 1,484 | 1,480 | 1,474 | 1,285 | 1,062 | 1,026 | 991 | 1,007 | 1,288 |
| 1941 | 1,611 | 1,800 | 1,800 | 1,800 | 1,800 | 1,792 | 1,676 | 1,630 | 1,625 | 1,744 | 1,760 | 1,800 |
| 1942 | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 | 1,792 | 1,681 | 1,653 | 1,647 | 1,732 | 1,748 | 1,797 |
| 1943 | 1,800 | 1,800 | 1,800 | 1,800 | 1,796 | 1,788 | 1,559 | 1,460 | 1,439 | 1,436 | 1,450 | 1,462 |
| 1944 | 1,480 | 1,494 | 1,509 | 1,513 | 1,509 | 1,503 | 1,306 | 1,032 | 912 | 851 | 852 | 862 |
| 1945 | 863 | 998 | 1,000 | 1,000 | 997 | 992 | 986 | 900 | 828 | 827 | 827 | 1,120 |
| 1946 | 1,376 | 1,376 | 1,376 | 1,374 | 1,370 | 1,364 | 1,220 | 931 | 872 | 805 | 810 | 820 |
| 1947 | 822 | 826 | 826 | 824 | 822 | 817 | 668 | 428 | 426 | 425 | 425 | 426 |
| 1948 | 427 | 427 | 431 | 449 | 447 | 444 | 441 | 438 | 435 | 434 | 434 | 436 |
| 1949 | 437 | 437 | 769 | 773 | 770 | 752 | 440 | 348 | 346 | 282 | 282 | 283 |
| 1950 | 290 | 395 | 395 | 397 | 395 | 392 | 389 | 386 | 384 | 383 | 389 | 666 |
| 1951 | 929 | 1,154 | 1,154 | 1,152 | 1,149 | 1,143 | 1,137 | 1,047 | 1,043 | 1,040 | 1,048 | 1,334 |
| 1952 | 1,719 | 1,800 | 1,800 | 1,800 | 1,800 | 1,792 | 1,784 | 1,776 | 1,783 | 1,800 | 1,800 | 1,800 |
| 1953 | 1,800 | 1,800 | 1,800 | 1,797 | 1,793 | 1,786 | 1,561 | 1,412 | 1,407 | 1,404 | 1,415 | 1,418 |
| 1954 | 1,653 | 1,800 | 1,800 | 1,800 | 1,796 | 1,566 | 1,246 | 1,036 | 993 | 963 | 993 | 1,081 |
| 1955 | 1,089 | 1,090 | 1,089 | 1,102 | 1,099 | 1,093 | 812 | 591 | 588 | 546 | 546 | 853 |
| 1956 | 1,222 | 1,482 | 1,488 | 1,511 | 1,741 | 1,734 | 1,587 | 1,558 | 1,553 | 1,690 | 1,695 | 1,701 |
| 1957 | 1,707 | 1,800 | 1,800 | 1,798 | 1,794 | 1,612 | 1,350 | 1,154 | 1,150 | 1,276 | 1,277 | 1,513 |
| 1958 | 1,786 | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 | 1,753 | 1,745 | 1,800 | 1,800 | 1,800 | 1,800 |
| 1959 | 1,800 | 1,800 | 1,800 | 1,797 | 1,793 | 1,507 | 1,175 | 878 | 874 | 790 | 790 | 793 |
| 1960 | 801 | 882 | 882 | 880 | 878 | 873 | 836 | 563 | 508 | 450 | 457 | 471 |
| 1961 | 512 | 726 | 737 | 736 | 733 | 729 | 457 | 304 | 302 | 218 | 218 | 237 |
| 1962 | 237 | 516 | 612 | 611 | 608 | 605 | 596 | 373 | 371 | 416 | 417 | 656 |
| 1963 | 658 | 917 | 973 | 1,219 | 1,216 | 1,210 | 1,203 | 1,197 | 1,192 | 1,234 | 1,472 | 1,475 |
| 1964 | 1,482 | 1,483 | 1,490 | 1,488 | 1,485 | 1,478 | 1,231 | 970 | 875 | 812 | 821 | 1,065 |
| 1965 | 1,358 | 1,359 | 1,358 | 1,599 | 1,596 | 1,589 | 1,433 | 1,389 | 1,384 | 1,381 | 1,626 | 1,632 |
| 1966 | 1,800 | 1,800 | 1,800 | 1,798 | 1,794 | 1,607 | 1,339 | 1,056 | 977 | 809 | 829 | 1,096 |
| 1967 | 1,390 | 1,625 | 1,800 | 1,800 | 1,800 | 1,800 | 1,791 | 1,783 | 1,777 | 1,800 | 1,800 | 1,800 |
| 1968 | 1,800 | 1,800 | 1,800 | 1,798 | 1,794 | 1,526 | 1,237 | 1,016 | 936 | 905 | 907 | 1,126 |
| 1969 | 1,455 | 1,800 | 1,800 | 1,800 | 1,800 | 1,792 | 1,784 | 1,776 | 1,800 | 1,800 | 1,800 | 1,800 |
| 1970 | 1,800 | 1,800 | 1,800 | 1,798 | 1,794 | 1,672 | 1,321 | 1,049 | 992 | 956 | 1,195 | 1,484 |
| 1971 | 1,735 | 1,736 | 1,800 | 1,798 | 1,794 | 1,786 | 1,565 | 1,398 | 1,393 | 1,391 | 1,396 | 1,404 |
| 1972 | 1,406 | 1,406 | 1,645 | 1,643 | 1,639 | 1,580 | 1,309 | 1,019 | 1,015 | 1,012 | 1,047 | 1,220 |
| 1973 | 1,613 | 1,800 | 1,800 | 1,798 | 1,794 | 1,641 | 1,403 | 1,230 | 1,226 | 1,223 | 1,479 | 1,746 |
| 1974 | 1,800 | 1,800 | 1,800 | 1,800 | 1,796 | 1,788 | 1,704 | 1,696 | 1,754 | 1,800 | 1,800 | 1,800 |
| 1975 | 1,800 | 1,800 | 1,800 | 1,798 | 1,794 | 1,786 | 1,608 | 1,600 | 1,607 | 1,800 | 1,800 | 1,800 |
| 1976 | 1,800 | 1,800 | 1,800 | 1,797 | 1,793 | 1,560 | 1,205 | 969 | 893 | 811 | 812 | 814 |
| 1977 | 815 | 816 | 815 | 814 | 811 | 543 | 514 | 424 | 358 | 288 | 289 | 293 |
| 1978 | 707 | 1,026 | 1,335 | 1,568 | 1,565 | 1,558 | 1,527 | 1,452 | 1,447 | 1,444 | 1,451 | 1,454 |
| 1979 | 1,486 | 1,668 | 1,749 | 1,754 | 1,750 | 1,589 | 1,329 | 1,148 | 1,105 | 1,103 | 1,125 | 1,217 |
| 1980 | 1,556 | 1,800 | 1,800 | 1,798 | 1,794 | 1,786 | 1,553 | 1,497 | 1,492 | 1,489 | 1,490 | 1,503 |
| 1981 | 1,628 | 1,760 | 1,800 | 1,798 | 1,794 | 1,546 | 1,253 | 995 | 934 | 923 | 1,190 | 1,483 |
| 1982 | 1,800 | 1,800 | 1,800 | 1,800 | 1,796 | 1,788 | 1,749 | 1,742 | 1,800 | 1,800 | 1,800 | 1,800 |
| 1983 | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 | 1,791 | 1,783 | 1,800 | 1,800 | 1,800 | 1,800 |
| 1984 | 1,800 | 1,800 | 1,800 | 1,798 | 1,794 | 1,680 | 1,423 | 1,208 | 1,203 | 1,201 | 1,485 | 1,549 |
| 1985 | 1,556 | 1,556 | 1,556 | 1,566 | 1,562 | 1,471 | 1,168 | 921 | 884 | 810 | 810 | 843 |
| 1986 | 879 | 1,257 | 1,593 | 1,606 | 1,602 | 1,595 | 1,384 | 1,314 | 1,309 | 1,307 | 1,307 | 1,312 |
| 1987 | 1,317 | 1,340 | 1,504 | 1,502 | 1,498 | 1,312 | 949 | 682 | 605 | 537 | 538 | 555 |
| 1988 | 699 | 699 | 699 | 697 | 695 | 580 | 428 | 416 | 367 | 273 | 273 | 274 |
| 1989 | 274 | 275 | 519 | 532 | 530 | 527 | 523 | 385 | 383 | 382 | 382 | 383 |
| 1990 | 393 | 393 | 401 | 400 | 398 | 395 | 365 | 362 | 360 | 229 | 230 | 230 |
| 1991 | 231 | 231 | 275 | 287 | 286 | 284 | 281 | 279 | 271 | 249 | 249 | 250 |
| 1992 | 255 | 354 | 383 | 382 | 380 | 378 | 345 | 342 | 323 | 229 | 229 | 239 |
| 1993 | 639 | 1,009 | 1,277 | 1,500 | 1,496 | 1,489 | 1,481 | 1,439 | 1,434 | 1,432 | 1,432 | 1,452 |
| 1994 | 1,461 | 1,491 | 1,491 | 1,494 | 1,491 | 1,436 | 1,138 | 908 | 832 | ---- | ---- | ---- |
| | | | | | | | | | | | | |
| AVG: | 1,125 | 1,218 | 1,267 | 1,289 | 1,290 | 1,231 | 1,086 | 968 | 946 | 933 | 963 | 1,029 |
| MIN: | 197 | 211 | 226 | 232 | 231 | 229 | 222 | 210 | 178 | 102 | 104 | 120 |
| MAX: | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 | 1,791 | 1,783 | 1,800 | 1,800 | 1,800 | 1,800 |

## Table 7 - Study 656: Sites Reservoir head in FEET

(originally titled by Planning as end-of-month elevation)

NOTE: Per Division of Planning and Local Assistance, this will be used as head (difference in elevation between Funks & Sites) in the calculations.

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 239 | 239 | 240 |
| 1922 | 243 | 252 | 253 | 253 | 253 | 253 | 252 | 252 | 251 | 251 | 252 | 259 |
| 1923 | 262 | 264 | 264 | 264 | 264 | 263 | 260 | 241 | 241 | 235 | 235 | 236 |
| 1924 | 237 | 238 | 240 | 240 | 239 | 192 | 159 | 155 | 144 | 140 | 141 | 144 |
| 1925 | 151 | 194 | 197 | 198 | 198 | 197 | 195 | 184 | 184 | 182 | 185 | 187 |
| 1926 | 190 | 220 | 221 | 222 | 222 | 221 | 207 | 183 | 182 | 173 | 176 | 184 |
| 1927 | 204 | 238 | 247 | 264 | 264 | 263 | 263 | 258 | 258 | 257 | 270 | 271 |
| 1928 | 274 | 290 | 295 | 295 | 295 | 278 | 255 | 236 | 226 | 217 | 217 | 217 |
| 1929 | 219 | 220 | 222 | 222 | 222 | 217 | 167 | 151 | 149 | 127 | 132 | 137 |
| 1930 | 143 | 145 | 150 | 151 | 151 | 150 | 150 | 149 | 149 | 149 | 149 | 149 |
| 1931 | 152 | 153 | 156 | 156 | 156 | 153 | 123 | 122 | 100 | 67 | 72 | 76 |
| 1932 | 83 | 89 | 96 | 98 | 97 | 97 | 96 | 95 | 95 | 94 | 94 | 96 |
| 1933 | 101 | 104 | 111 | 112 | 111 | 111 | 110 | 109 | 108 | 105 | 105 | 107 |
| 1934 | 112 | 115 | 122 | 123 | 122 | 121 | 94 | 89 | 75 | 43 | 44 | 51 |
| 1935 | 95 | 113 | 119 | 172 | 172 | 171 | 171 | 170 | 162 | 161 | 162 | 165 |
| 1936 | 208 | 238 | 240 | 240 | 240 | 240 | 239 | 231 | 226 | 224 | 225 | 226 |
| 1937 | 227 | 241 | 258 | 258 | 258 | 255 | 236 | 221 | 211 | 211 | 234 | 256 |
| 1938 | 263 | 282 | 295 | 295 | 295 | 294 | 290 | 290 | 289 | 295 | 295 | 295 |
| 1939 | 295 | 295 | 295 | 295 | 295 | 273 | 243 | 208 | 199 | 187 | 187 | 190 |
| 1940 | 226 | 249 | 267 | 273 | 273 | 272 | 259 | 243 | 241 | 238 | 239 | 260 |
| 1941 | 282 | 295 | 295 | 295 | 295 | 294 | 286 | 283 | 283 | 291 | 292 | 295 |
| 1942 | 295 | 295 | 295 | 295 | 295 | 294 | 287 | 285 | 284 | 290 | 291 | 295 |
| 1943 | 295 | 295 | 295 | 295 | 295 | 294 | 278 | 271 | 270 | 270 | 271 | 271 |
| 1944 | 273 | 273 | 275 | 275 | 275 | 274 | 261 | 241 | 228 | 221 | 221 | 222 |
| 1945 | 222 | 239 | 239 | 239 | 238 | 238 | 237 | 227 | 218 | 218 | 218 | 248 |
| 1946 | 266 | 266 | 266 | 266 | 265 | 265 | 255 | 230 | 223 | 215 | 216 | 217 |
| 1947 | 217 | 218 | 218 | 218 | 217 | 217 | 199 | 157 | 157 | 157 | 157 | 157 |
| 1948 | 157 | 157 | 158 | 161 | 161 | 160 | 160 | 159 | 159 | 158 | 159 | 159 |
| 1949 | 159 | 159 | 211 | 211 | 211 | 209 | 160 | 144 | 144 | 119 | 119 | 120 |
| 1950 | 123 | 152 | 152 | 152 | 152 | 151 | 151 | 150 | 150 | 150 | 151 | 199 |
| 1951 | 230 | 250 | 250 | 250 | 250 | 249 | 249 | 242 | 242 | 242 | 242 | 263 |
| 1952 | 289 | 295 | 295 | 295 | 295 | 294 | 294 | 293 | 294 | 295 | 295 | 295 |
| 1953 | 295 | 295 | 295 | 295 | 295 | 294 | 278 | 268 | 268 | 268 | 268 | 268 |
| 1954 | 285 | 295 | 295 | 295 | 295 | 279 | 257 | 241 | 238 | 234 | 238 | 245 |
| 1955 | 245 | 245 | 245 | 246 | 246 | 246 | 216 | 185 | 185 | 178 | 178 | 221 |
| 1956 | 255 | 273 | 273 | 275 | 291 | 290 | 280 | 278 | 278 | 287 | 288 | 288 |
| 1957 | 288 | 295 | 295 | 295 | 295 | 282 | 264 | 250 | 250 | 259 | 259 | 275 |
| 1958 | 294 | 295 | 295 | 295 | 295 | 295 | 292 | 291 | 295 | 295 | 295 | 295 |
| 1959 | 295 | 295 | 295 | 295 | 295 | 274 | 251 | 224 | 224 | 214 | 214 | 214 |
| 1960 | 215 | 225 | 225 | 224 | 224 | 223 | 219 | 181 | 171 | 161 | 162 | 165 |
| 1961 | 172 | 206 | 207 | 207 | 207 | 206 | 162 | 128 | 128 | 92 | 92 | 100 |
| 1962 | 100 | 172 | 189 | 189 | 188 | 188 | 186 | 148 | 148 | 156 | 156 | 197 |
| 1963 | 197 | 229 | 236 | 255 | 254 | 254 | 254 | 253 | 253 | 256 | 272 | 272 |
| 1964 | 273 | 273 | 273 | 273 | 273 | 272 | 255 | 235 | 224 | 216 | 217 | 244 |
| 1965 | 265 | 265 | 265 | 281 | 281 | 280 | 269 | 267 | 266 | 266 | 283 | 283 |
| 1966 | 295 | 295 | 295 | 295 | 295 | 281 | 263 | 243 | 236 | 216 | 218 | 246 |
| 1967 | 267 | 283 | 295 | 295 | 295 | 295 | 294 | 294 | 293 | 295 | 295 | 295 |
| 1968 | 295 | 295 | 295 | 295 | 295 | 276 | 256 | 240 | 231 | 227 | 228 | 248 |
| 1969 | 271 | 295 | 295 | 295 | 295 | 294 | 294 | 293 | 295 | 295 | 295 | 295 |
| 1970 | 295 | 295 | 295 | 295 | 295 | 286 | 262 | 242 | 238 | 233 | 253 | 273 |
| 1971 | 290 | 290 | 295 | 295 | 295 | 294 | 278 | 267 | 267 | 267 | 267 | 268 |
| 1972 | 268 | 268 | 284 | 284 | 284 | 280 | 261 | 240 | 240 | 240 | 242 | 255 |
| 1973 | 282 | 295 | 295 | 295 | 295 | 284 | 268 | 255 | 255 | 255 | 272 | 291 |
| 1974 | 295 | 295 | 295 | 295 | 295 | 294 | 288 | 288 | 292 | 295 | 295 | 295 |
| 1975 | 295 | 295 | 295 | 295 | 295 | 294 | 281 | 281 | 281 | 295 | 295 | 295 |
| 1976 | 295 | 295 | 295 | 295 | 295 | 278 | 254 | 235 | 226 | 216 | 216 | 216 |
| 1977 | 217 | 217 | 217 | 216 | 216 | 177 | 172 | 157 | 146 | 122 | 122 | 124 |
| 1978 | 204 | 241 | 263 | 279 | 278 | 278 | 276 | 271 | 270 | 270 | 271 | 271 |
| 1979 | 273 | 286 | 291 | 292 | 291 | 280 | 263 | 250 | 246 | 246 | 248 | 255 |
| 1980 | 278 | 295 | 295 | 295 | 295 | 294 | 278 | 274 | 273 | 273 | 273 | 274 |
| 1981 | 283 | 292 | 295 | 295 | 295 | 277 | 257 | 238 | 231 | 230 | 253 | 273 |
| 1982 | 295 | 295 | 295 | 295 | 295 | 294 | 291 | 291 | 295 | 295 | 295 | 295 |
| 1983 | 295 | 295 | 295 | 295 | 295 | 295 | 294 | 294 | 295 | 295 | 295 | 295 |
| 1984 | 295 | 295 | 295 | 295 | 295 | 287 | 269 | 254 | 254 | 253 | 273 | 277 |
| 1985 | 278 | 278 | 278 | 279 | 278 | 272 | 251 | 229 | 225 | 216 | 216 | 220 |
| 1986 | 224 | 257 | 280 | 281 | 281 | 281 | 266 | 261 | 261 | 261 | 261 | 261 |
| 1987 | 262 | 263 | 274 | 274 | 274 | 261 | 233 | 201 | 188 | 176 | 176 | 179 |
| 1988 | 203 | 203 | 203 | 202 | 202 | 184 | 157 | 156 | 147 | 115 | 115 | 116 |
| 1989 | 116 | 116 | 173 | 175 | 175 | 174 | 173 | 150 | 150 | 150 | 150 | 150 |
| 1990 | 152 | 152 | 153 | 153 | 152 | 152 | 147 | 146 | 146 | 97 | 97 | 97 |
| 1991 | 98 | 98 | 116 | 121 | 121 | 120 | 119 | 118 | 114 | 105 | 105 | 106 |
| 1992 | 108 | 145 | 150 | 150 | 149 | 149 | 143 | 143 | 137 | 97 | 97 | 101 |
| 1993 | 194 | 239 | 259 | 274 | 274 | 273 | 273 | 270 | 270 | 269 | 269 | 271 |
| 1994 | 271 | 273 | 273 | 274 | 273 | 270 | 249 | 228 | 219 | --- | --- | --- |
| AVG: | 231 | 242 | 247 | 249 | 249 | 244 | 231 | 220 | 216 | 211 | 214 | 220 |
| MIN: | 83 | 89 | 96 | 98 | 97 | 97 | 94 | 89 | 75 | 43 | 44 | 51 |
| MAX: | 295 | 295 | 295 | 295 | 295 | 295 | 294 | 294 | 295 | 295 | 295 | 295 |

**Table 8 - Average monthly head (difference in elevation between Funks & Sites) used in the study, FEET**

NOTE: The current monthly average head is the sum of the previous and current end-of-the-month's elevation divided by two.

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 239 | 239.5 |
| 1922 | 241.5 | 247.5 | 252.5 | 253 | 253 | 253 | 252.5 | 252 | 251.5 | 251 | 251.5 | 255.5 |
| 1923 | 260.5 | 263 | 264 | 264 | 264 | 263.5 | 261.5 | 250.5 | 241 | 238 | 235 | 235.5 |
| 1924 | 236.5 | 237.5 | 239 | 240 | 239.5 | 215.5 | 175.5 | 157 | 149.5 | 142 | 140.5 | 142.5 |
| 1925 | 147.5 | 172.5 | 195.5 | 197.5 | 198 | 197.5 | 196 | 189.5 | 184 | 183 | 183.5 | 186 |
| 1926 | 188.5 | 205 | 220.5 | 221.5 | 222 | 221.5 | 214 | 195 | 182.5 | 177.5 | 174.5 | 180 |
| 1927 | 194 | 221 | 242.5 | 255.5 | 264 | 263.5 | 263 | 260.5 | 258 | 257.5 | 263.5 | 270.5 |
| 1928 | 272.5 | 282 | 292.5 | 295 | 295 | 286.5 | 266.5 | 245.5 | 231 | 221.5 | 217 | 217 |
| 1929 | 218 | 219.5 | 221 | 222 | 222 | 219.5 | 192 | 159 | 150 | 138 | 129.5 | 134.5 |
| 1930 | 140 | 144 | 147.5 | 150.5 | 151 | 150.5 | 150 | 149.5 | 149 | 149 | 149 | 149 |
| 1931 | 150.5 | 152.5 | 154.5 | 156 | 156 | 154.5 | 138 | 122.5 | 111 | 83.5 | 69.5 | 74 |
| 1932 | 79.5 | 86 | 92.5 | 97 | 97.5 | 97 | 96.5 | 95.5 | 95 | 94.5 | 94 | 95 |
| 1933 | 98.5 | 102.5 | 107.5 | 111.5 | 111.5 | 111 | 110.5 | 109.5 | 108.5 | 106.5 | 105 | 106 |
| 1934 | 109.5 | 113.5 | 118.5 | 122.5 | 122.5 | 121.5 | 107.5 | 91.5 | 82 | 59 | 43.5 | 47.5 |
| 1935 | 73 | 104 | 116 | 145.5 | 172 | 171.5 | 171 | 170.5 | 166 | 161.5 | 161.5 | 163.5 |
| 1936 | 186.5 | 223 | 239 | 240 | 240 | 240 | 239.5 | 235 | 228.5 | 225 | 224.5 | 225.5 |
| 1937 | 226.5 | 234 | 249.5 | 258 | 258 | 256.5 | 245.5 | 228.5 | 216 | 211 | 222.5 | 245 |
| 1938 | 259.5 | 272.5 | 288.5 | 295 | 295 | 294.5 | 292 | 290 | 289.5 | 292 | 295 | 295 |
| 1939 | 295 | 295 | 295 | 295 | 295 | 284 | 258 | 225.5 | 203.5 | 193 | 187 | 188.5 |
| 1940 | 208 | 237.5 | 258 | 270 | 273 | 272.5 | 265.5 | 251 | 242 | 239.5 | 238.5 | 249.5 |
| 1941 | 271 | 288.5 | 295 | 295 | 295 | 294.5 | 290 | 284.5 | 283 | 287 | 291.5 | 293.5 |
| 1942 | 295 | 295 | 295 | 295 | 295 | 294.5 | 290.5 | 286 | 284.5 | 287 | 290.5 | 293 |
| 1943 | 295 | 295 | 295 | 295 | 295 | 294.5 | 286 | 274.5 | 270.5 | 270 | 270.5 | 271 |
| 1944 | 272 | 273 | 274 | 275 | 275 | 274.5 | 267.5 | 251 | 234.5 | 224.5 | 221 | 221.5 |
| 1945 | 222 | 230.5 | 239 | 239 | 238.5 | 238 | 237.5 | 232 | 222.5 | 218 | 218 | 233 |
| 1946 | 257 | 266 | 266 | 266 | 265.5 | 265 | 260 | 242.5 | 226.5 | 219 | 215.5 | 216.5 |
| 1947 | 217 | 217.5 | 218 | 218 | 217.5 | 217 | 208 | 178 | 157 | 157 | 157 | 157 |
| 1948 | 157 | 157 | 157.5 | 159.5 | 161 | 160.5 | 160 | 159.5 | 159 | 158.5 | 158.5 | 159 |
| 1949 | 159 | 159 | 185 | 211 | 211 | 210 | 184.5 | 152 | 144 | 131.5 | 119 | 119.5 |
| 1950 | 121.5 | 137.5 | 152 | 152 | 152 | 151.5 | 151 | 150.5 | 150 | 150 | 150.5 | 175 |
| 1951 | 214.5 | 240 | 250 | 250 | 250 | 249.5 | 249 | 245.5 | 242 | 242 | 242 | 252.5 |
| 1952 | 276 | 292 | 295 | 295 | 295 | 294.5 | 294 | 293.5 | 293.5 | 294.5 | 295 | 295 |
| 1953 | 295 | 295 | 295 | 295 | 295 | 294.5 | 286 | 273 | 268 | 268 | 268 | 268 |
| 1954 | 276.5 | 290 | 295 | 295 | 295 | 287 | 268 | 249 | 239.5 | 236 | 236 | 241.5 |
| 1955 | 245 | 245 | 245 | 245.5 | 246 | 246 | 231 | 200.5 | 185 | 181.5 | 178 | 199.5 |
| 1956 | 238 | 264 | 273 | 274 | 283 | 290.5 | 285 | 279 | 278 | 282.5 | 287.5 | 288 |
| 1957 | 288 | 291.5 | 295 | 295 | 295 | 288.5 | 273 | 257 | 250 | 254.5 | 259 | 267 |
| 1958 | 284.5 | 294.5 | 295 | 295 | 295 | 295 | 293.5 | 291.5 | 293 | 295 | 295 | 295 |
| 1959 | 295 | 295 | 295 | 295 | 295 | 284.5 | 262.5 | 237.5 | 224 | 219 | 214 | 214 |
| 1960 | 214.5 | 220 | 225 | 224.5 | 224 | 223.5 | 221 | 200 | 176 | 166 | 161.5 | 163.5 |
| 1961 | 168.5 | 189 | 206.5 | 207 | 207 | 206.5 | 184 | 145 | 128 | 110 | 92 | 96 |
| 1962 | 100 | 136 | 180.5 | 189 | 188.5 | 188 | 187 | 167 | 148 | 152 | 156 | 176.5 |
| 1963 | 197 | 213 | 232.5 | 245.5 | 254.5 | 254 | 254 | 253.5 | 253 | 254.5 | 264 | 272 |
| 1964 | 272.5 | 273 | 273 | 273 | 273 | 272.5 | 263.5 | 245 | 229.5 | 220 | 216.5 | 230.5 |
| 1965 | 254.5 | 265 | 265 | 273 | 281 | 280.5 | 274.5 | 268 | 266.5 | 266 | 274.5 | 283 |
| 1966 | 289 | 295 | 295 | 295 | 295 | 288 | 272 | 253 | 239.5 | 226 | 217 | 232 |
| 1967 | 256.5 | 275 | 289 | 295 | 295 | 295 | 294.5 | 294 | 293.5 | 294 | 295 | 295 |
| 1968 | 295 | 295 | 295 | 295 | 295 | 285.5 | 266 | 248 | 235.5 | 229 | 227.5 | 238 |
| 1969 | 259.5 | 283 | 295 | 295 | 295 | 294.5 | 294 | 293.5 | 294 | 295 | 295 | 295 |
| 1970 | 295 | 295 | 295 | 295 | 295 | 290.5 | 274 | 252 | 240 | 235.5 | 243 | 263 |
| 1971 | 281.5 | 290 | 292.5 | 295 | 295 | 294.5 | 286 | 272.5 | 267 | 267 | 267 | 267.5 |
| 1972 | 268 | 268 | 276 | 284 | 284 | 282 | 270.5 | 250.5 | 240 | 240 | 241 | 248.5 |
| 1973 | 268.5 | 288.5 | 295 | 295 | 295 | 289.5 | 276 | 261.5 | 255 | 255 | 263.5 | 281.5 |
| 1974 | 293 | 295 | 295 | 295 | 295 | 294.5 | 291 | 288 | 290 | 293.5 | 295 | 295 |
| 1975 | 295 | 295 | 295 | 295 | 295 | 294.5 | 287.5 | 281 | 281 | 288 | 295 | 295 |
| 1976 | 295 | 295 | 295 | 295 | 295 | 286.5 | 266 | 244.5 | 230.5 | 221 | 216 | 216 |
| 1977 | 216.5 | 217 | 217 | 216.5 | 216 | 196.5 | 174.5 | 164.5 | 151.5 | 134 | 122 | 123 |
| 1978 | 164 | 222.5 | 252 | 271 | 278.5 | 278 | 277 | 273.5 | 270.5 | 270 | 270.5 | 271 |
| 1979 | 272 | 279.5 | 288.5 | 291.5 | 291.5 | 285.5 | 271.5 | 256.5 | 248 | 246 | 247 | 251.5 |
| 1980 | 266.5 | 286.5 | 295 | 295 | 295 | 294.5 | 286 | 276 | 273.5 | 273 | 273 | 273.5 |
| 1981 | 278.5 | 287.5 | 293.5 | 295 | 295 | 286 | 267 | 247.5 | 234.5 | 230.5 | 241.5 | 263 |
| 1982 | 284 | 295 | 295 | 295 | 295 | 294.5 | 292.5 | 291 | 293 | 295 | 295 | 295 |
| 1983 | 295 | 295 | 295 | 295 | 295 | 295 | 294.5 | 294 | 294.5 | 295 | 295 | 295 |
| 1984 | 295 | 295 | 295 | 295 | 295 | 291 | 278 | 261.5 | 254 | 253.5 | 263 | 275 |
| 1985 | 277.5 | 278 | 278 | 278.5 | 278.5 | 275 | 261.5 | 240 | 227 | 220.5 | 216 | 218 |
| 1986 | 222 | 240.5 | 268.5 | 280.5 | 281 | 281 | 273.5 | 263.5 | 261 | 261 | 261 | 261 |
| 1987 | 261.5 | 262.5 | 268.5 | 274 | 274 | 267.5 | 247 | 217 | 194.5 | 182 | 176 | 177.5 |
| 1988 | 191 | 203 | 203 | 202.5 | 202 | 193 | 170.5 | 156.5 | 151.5 | 131 | 115 | 115.5 |
| 1989 | 116 | 116 | 144.5 | 174 | 175 | 174.5 | 173.5 | 161.5 | 150 | 150 | 150 | 150 |
| 1990 | 151 | 152 | 152.5 | 153 | 152.5 | 152 | 149.5 | 146.5 | 146 | 121.5 | 97 | 97 |
| 1991 | 97.5 | 98 | 107 | 118.5 | 121 | 120.5 | 119.5 | 118.5 | 116 | 109.5 | 105 | 105.5 |
| 1992 | 107 | 126.5 | 147.5 | 150 | 149.5 | 149 | 146 | 143 | 140 | 117 | 97 | 99 |
| 1993 | 147.5 | 216.5 | 249 | 266.5 | 274 | 273.5 | 273 | 271.5 | 270 | 269.5 | 269 | 270 |
| 1994 | 271 | 272 | 273 | 273.5 | 273.5 | 271.5 | 259.5 | 238.5 | 223.5 | 0 | 0 | 0 |
| AVG: | 225.8 | 236.3 | 244.3 | 248.0 | 249.1 | 246.6 | 237.6 | 225.4 | 217.9 | 213.5 | 212.4 | 217.1 |
| MIN: | 73 | 86 | 92.5 | 97 | 97.5 | 97 | 96.5 | 91.5 | 82 | 59 | 43.5 | 47.5 |
| MAX: | 295 | 295 | 295 | 295 | 295 | 295 | 294.5 | 294 | 294.5 | 295 | 295 | 295 |

April 27, 1999

Mr. Frank Tsai
Pacific Gas and Electric Company
Electric Transmission Services
77 Beale Street
San Francisco, California 94105

Dear Mr. Tsai:

We received your letter regarding the informational review of the proposed Sites Offstream Reservoir Pumped-Storage Hydroelectric Project transmission interconnection. Your letter will be part of an overall report on the proposed Sites Offstream Reservoir Project.

The report will be submitted to our Northern District in Red Bluff which is leading the study on the proposed project. After Northern District's review, a decision will be made on how to proceed with the proposed project, including the transmission interconnection for the pumped-storage and probable additional pumping or pumped-storage plants. You will then receive a letter on whether to proceed with the preliminary facilities study or a detailed facilities study.

For your information, the location of the proposed pumped-storage shown in Figure 1 of your informational review is incorrect. A copy of Figure 1 marked with the correct approximate location of the proposed pumped-storage plant and a map of the proposed Sites Offstream Reservoir is enclosed.

If you should have any questions or require further information on this matter, please call me at (916) 653-6271 or Sonny Punzalan at (916) 653-9551.

Sincerely,

ORIGINAL SIGNED BY

Chi Doan
Power Supply
and Transmission Planning

SPunzalan:rm
C:\Rebecca's Folder\FrankTsailtr.doc
SPELLCHECKED

APPROXIMATE LOCATION OF PROPOSED SITES RESERVOIR

APPROXIMATE LOCATION OF PUMPED-STORAGE

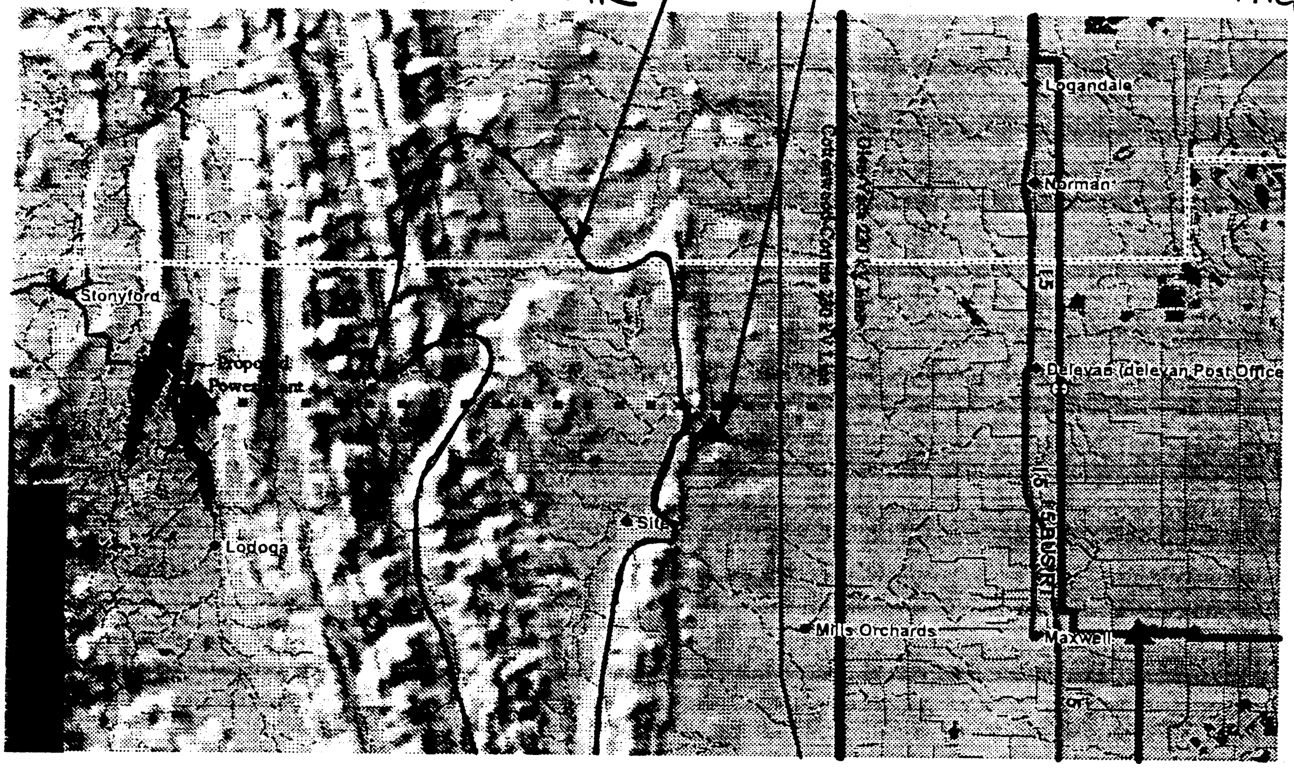


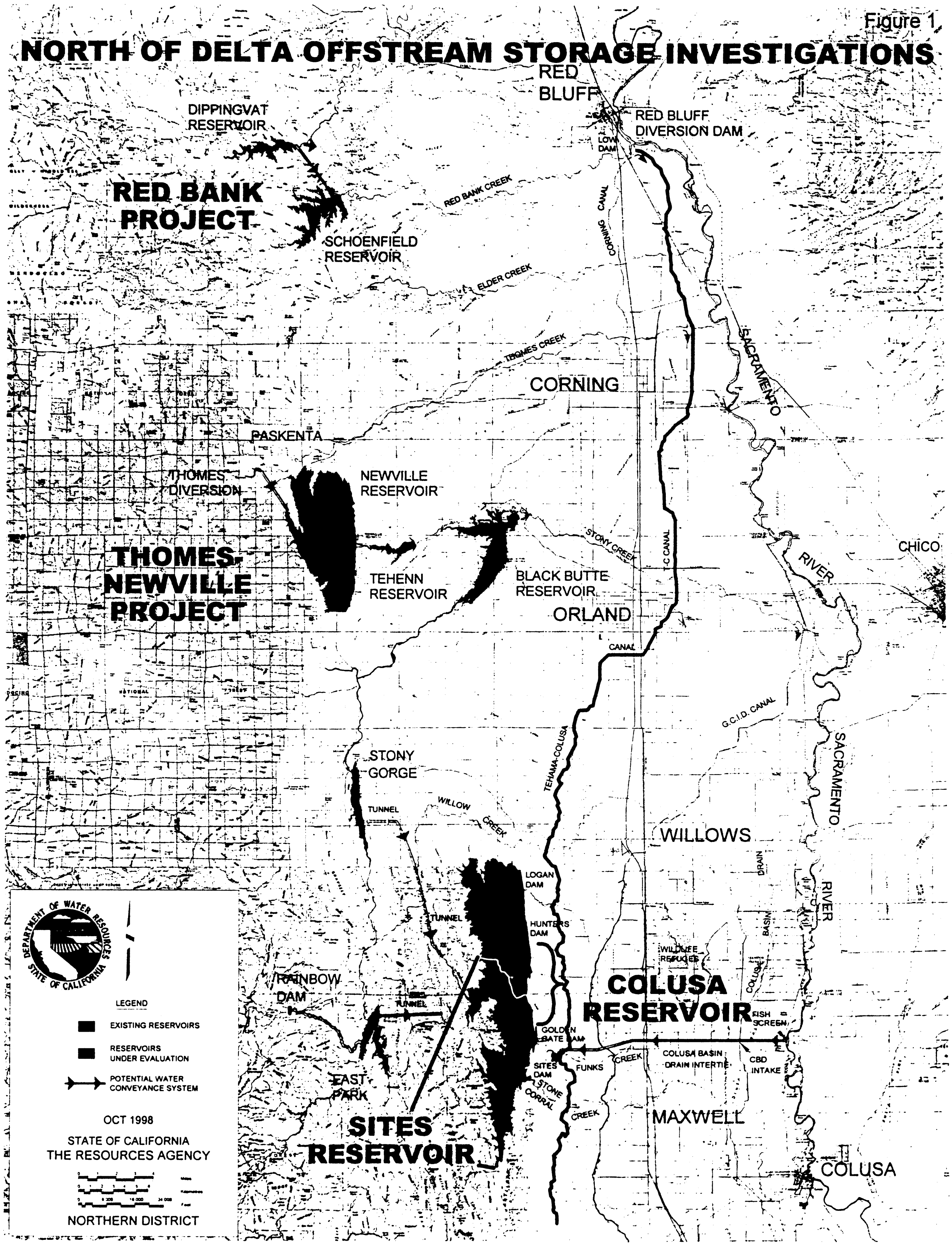

**Figure 1 - Proposed Pump Storage Hydroelectric Facility**

| | Proposed Work | Rough Cost ($000) |
|---|---|---|
| 1 | Loop Cottonwood-Cortina 230 kV line into CDWR's facility (approx. 15 miles each way) | $ 5,000 |
| 2 | Loop Glenn-Vaca 230 kV line into CDWR's facility (approx. 15 miles each way) | $ 5,000 |
| 3 | Protection Upgrades on the Cottonwood-Cortina 230 kV line | $ 400 |
| 3 | Protection Upgrades on the Glenn-Vaca 230 kV line | $ 400 |
| 4 | Construct a 6-breaker ring bus Switching Station on CDWR's facility | $ 6,000 |
| | **TOTAL** | **$16,800** |

**Table 1 - Proposed Interconnection Facilities**

Figure 1

# NORTH OF DELTA OFFSTREAM STORAGE INVESTIGATIONS

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Pacific Gas and Electric Company

Electric Transmission Services

77 Beale Street
San Francisco, CA 94105

*Mailing Address*
Mail Code B23A
P.O. Box 770000
San Francisco, CA 94177

415.973.7000

April 12, 1999

Mr. Arsenio F. Punzalan
California Department of Water Resources
Power Supply and Transmission Planning - Room 1655
1416 Ninth Street
Sacramento, CA 95814

**Subject: Informational Review - Sites Offstream Pump Storage Hydro Project**

Dear Sonny:

As CDWR requested, PG&E has performed an Informational Review for the proposal to interconnect a pump storage hydroelectric generating facility under consideration near Maxwell to PG&E's transmission grid. This review is based on the assumption that the proposed generating facility is capable of producing a maximum of 162 MW of power in the generating mode and requires a demand of 300 MW in the pumping mode.

As part of our effort to provide an Informational Review, we have reviewed our existing studies, used engineering judgment and performed a few preliminary powerflow analysis using standard base cases under normal and emergency conditions. Review conclusions and a non-binding indication of the order-of-magnitude cost estimate for the interconnection option considered are summarized in the attached report. The review results must be validated by an interconnection study and the costs to perform either a Preliminary Facilities Study or a Detailed Facilities Study will be provided upon request when you are ready to proceed further.

Should you have any questions, please do not hesitate to call me at (415) 973-0437.

Sincerely,

Frank Tsai

Attachment

# Informational Review

## Sites Offstream Pump Storage Hydroelectric Project

PG&E

Pacific Gas and Electric Company

April 12, 1999

**INFORMATIONAL REVIEW**
**(Confidential)**

## Background

As requested by California Department of Water Resources (CDWR), PG&E has completed an Informational Review for CDWR's proposed pump storage hydroelectric facility located in Sites Reservoir in Colusa County. In the generating mode, the facility would have a capability of 162 MW and in the pumping mode a demand of 200 MW. CDWR also indicated that the ultimate demand of the facility in the pumping mode would be about 300 MW. This report summaries PG&E's Informational Review using screening level information to provide a non-binding rough cost estimate for the interconnection facilities.

Please also note that this review only addresses the transmission interconnection and substation aspect for the proposed project.

## Objective of Information Review

This Informational Review gives CDWR a quick, no cost, non-binding indication of the order-of-magnitude cost for service connection to the PG&E's transmission grid. This review, on which typically a maximum of two days of study time is spent, is based on past experience with similar requests and previously conducted studies, where available. This approach can save both CDWR and PG&E time and resources when CDWR is considering its own options and is only seeking general feasibility information. A request for an Informational Review is not considered a formal request for interconnection.

All costs provided in this Information Review have no intended degree of accuracy and are based on typical per unit cost. The costs does not include the cost of land right-of-way, income tax component of contribution (ITCC) tax or cost of ownership (COC) charges. ITCC and COC typically add approximately 75% to the cost. Cost of facilities to be constructed, owned and maintained by the customer is also not included.

Information and findings stated in this review must be validated by a PG&E interconnection study if CDWR decides to proceed further.

## Interconnection Facilities

Based on the information provided by CDWR, it appears that the proposed project site would be located about 15 miles west of PG&E's Cottonwood-Cortina and Glenn-Vaca 230 kV transmission lines. (Figure 1) To accommodate the ultimate project size of 300 MW, PG&E explored the option of looping both the Cottonwood-Cortina and Glenn-Vaca 230 kV lines into a proposed switchyard to be located on the project site. The rough cost of the required interconnection facilities are tabulated in Table 1.

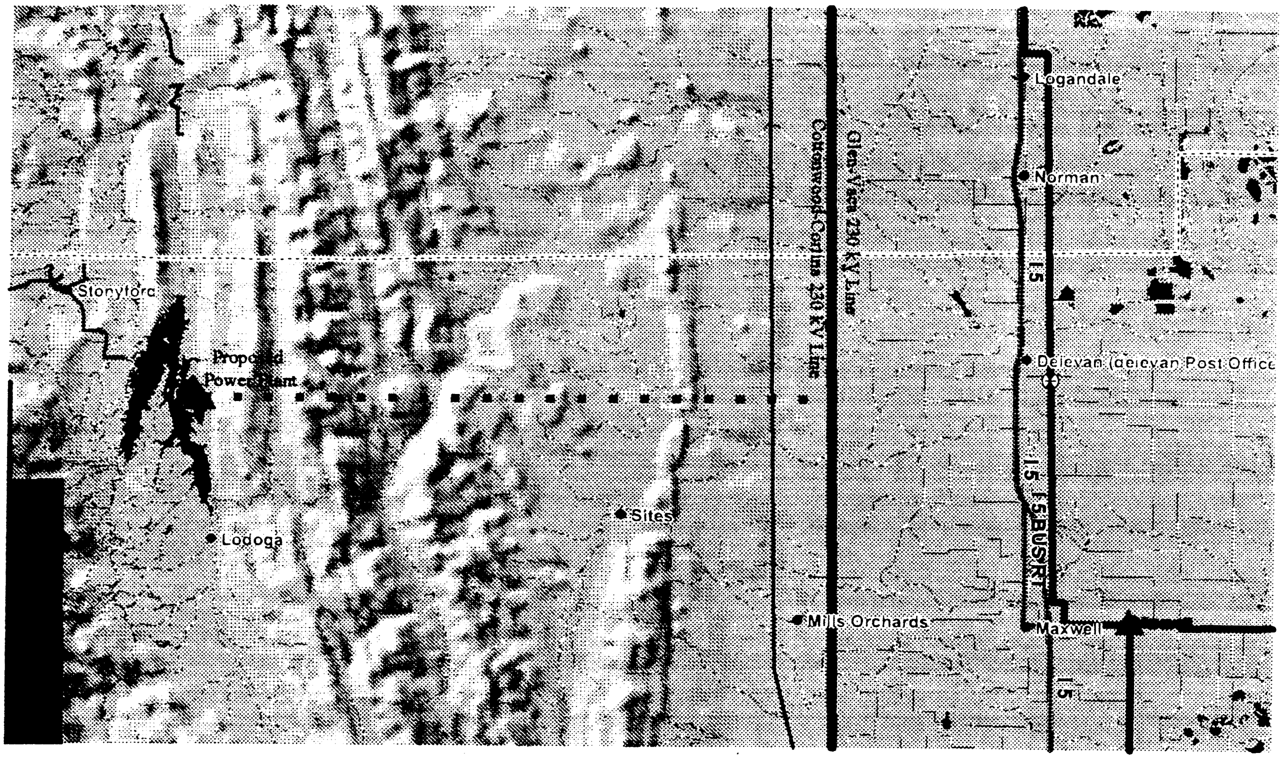


**Figure 1 - Proposed Pump Storage Hydroelectric Facility**

| | Proposed Work | Rough Cost ($000) |
|---|---|---|
| 1 | Loop Cottonwood-Cortina 230 kV line into CDWR's facility (approx. 15 miles each way) | $ 5,000 |
| 2 | Loop Glenn-Vaca 230 kV line into CDWR's facility (approx. 15 miles each way) | $ 5,000 |
| 3 | Protection Upgrades on the Cottonwood-Cortina 230 kV line | $ 400 |
| 3 | Protection Upgrades on the Glenn-Vaca 230 kV line | $ 400 |
| 4 | Construct a 6-breaker ring bus Switching Station on CDWR's facility | $ 6,000 |
| | **TOTAL** | **$16,800** |

**Table 1 - Proposed Interconnection Facilities**

## Transmission System Upgrade

On a screening analysis basis, we do not anticipate any need for major transmission system upgrades. System analyses such as power flow, short circuit and stability studies would have to be performed as part of the interconnection study.

## Next Step - System Impact Study

To continue with this proposed transmission interconnection, PG&E will perform either a Preliminary Facilities Study (PFS) or a Detailed Facilities Study (DFS), depending on the desired degree of the cost estimate accuracy. This work is necessary to determine specifically what interconnection facilities will be required to provide the proposed service and their associated cost estimates.

The optional PFS will study multiple interconnection alternatives and will provide non-binding cost estimates for the required interconnection facilities with an intended ±50 % accuracy. The PFS results are intended to help the customer gain information about the available alternatives and eventually select a preferred alternative for a DFS. The charge for the PFS will be based on the complexity and the number of alternatives to be studied. In most cases, a PFS will take 90 days to complete.

The DFS is required for any request for interconnection. It will provide a cost estimate, binding for 60 days from the date the DFS report is issued for a single interconnection alternative chosen by the customer and/or the associated system reinforcements. The charge for the DFS will be based on the complexity of the alternative. In most cases, a DFS will take 120 days to complete.

ASSUMPTIONS & FORMULAS

| | | | | |
|---|---|---|---|---|
| Plant Capacity = | 6800 cfs (P) | | | 9064 cfs (G) |
| Plant MW (Generate) = | Head * flow * Eff.* | | 0.746 | |
| | 1000 | 8.815 | | |
| Plant MW (Pump) = | Head * flow * . | | 11.3333 | 0.746 |
| | Eff. | 100000 | | |

| | | |
|---|---|---|
| Efficiency (Generate) = | 87.30% | - from EPRI GS-6669 (Jan. 1990) - Pumped-Storage Planning & Evaluation Guide |
| Efficiency (Pump) = | 87.70% | - from EPRI GS-6669 (Jan. 1990) - Pumped-Storage Planning & Evaluation Guide |
| Onpk Hours/Month = | 426 | |
| Offpk Hours/Month = | 304 | |
| Max. Onpk TAF through plant /month = | 319 | |
| Max. Offpk TAF through plant /month = | 171 | |

tate of California DEPARTMENT OF WATER RESOURCES The Resources Agency

# FFICE MEMO

| | |
|---|---|
| TO: Chi Doan | DATE: May 11, 1999 |
| FROM: Farshid Falaki | SUBJECT: Efficiency Assumption of the Proposed Pumped-Storage Hydroelectric Power Plant for Site Reservoir Project |

In reference to your office memo of May 5, 1999, my comments based on the plant flow capacity of 6,800 cfs during power generation and 280 feet head are as following:

1- Your assumption on turbine efficiency of 90 percent is reasonable.
2- The assumption on pump efficiency should be revised from 70 percent to 89 percent.

The above assumptions are made for a plant with six pump-turbines with following characteristics:

| | |
|---|---|
| $N$ = 400 rpm | (Unit Speed) |
| $Q_T$ = 1,133 cfs | (Turbine Rated Flow) |
| $P_T$ = 31,700 hp | (Generator Output based on 98% generator eff.) |
| $n_{ST}$ = 63 | (Turbine Specific Speed) |
| | |
| $Q_P$ = 850 cfs | (Pump Rated Flow) |
| $P_P$ = 30,950 hp | (Motor Input) |
| $n_{SP}$ = 3,609 | (Pump Specific Speed) |

Presently, Mechanical and Electrical Engineering Branch is not authorized to work on this project; however, Please do not hesitate to call me at 653-9848 if you have any further questions.

FROM EPRI GS-6669 (JAN. 1990) - PUMPED-STORAGE PLANNING & EVALUATION GUIDE

**Efficiency**

The modern pumped-storage plant has become quite efficient, where the term efficiency denotes cycle efficiency (ratio of energy output to energy input). Cycle efficiency has improved from under 65% for the early plants of the 1960's to over 75% for the newer plants. The overall efficiency includes the efficiencies of the water conductors, pump/turbines, generator/motors and transformers (if energy input and output are measured at the high side of the main transformers). For most pumped-storage plants, the efficiency is often determined from its energy production and consumption over a year. In that case, the overall operation such as unit startup, turn-around, part-load, and seal-ring losses in the pump/turbine would be factored in. In addition, losses in the reservoirs due to evaporation and seepage as well as gains due to local inflow are accounted for.

Efficiency is controlled to some extent by the plant design. For example, more elaborate design of the water conductors and intake/outlets reduces the hydraulic losses, and hence increases the cycle efficiency. A modern large pumped-storage plant is expected to have a cycle efficiency in the range of 72 to 80% depending on unit size, head variation, length of water conductors relative to head, design refinements, and how the plant is operated. Table 2-2 illustrates the individual component efficiencies for a typical plant having a cycle efficiency of about 75 %.

Table 2-2

COMPOSITION OF CYCLE EFFICIENCY - %

| | |
|---|---|
| GENERATING | |
| Water Conductors | 97.4 |
| Pump/Turbine | 91.5 |
| Generator/Motor | 98.5 |
| Transformer | 99.5 |
| Subtotal - Generating | 87.3 |
| PUMPING | |
| Water Conductors | 97.6 |
| Pump/Turbine | 91.5 |
| Generator/Motor | 98.7 |
| Transformer | 99.5 |
| Subtotal - Pumping | 87.7 |
| OPERATIONAL | |
| Losses/Leakage | 98.0 |
| TOTAL | 75.0 |

State of California
The Resources Agency
Department of Water Resources
Division of Planning and Local Assistance